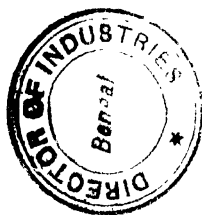


PRACTICAL TREATISE
ON
THE BLEACHING
OF
LINEN AND COTTON YARN
AND FABRICS

BY
L. TAILFER

CHEMICAL AND MECHANICAL ENGINEER



TRANSLATED FROM THE FRENCH BY
JOHN GEDDES MINTOSH

SECOND ENGLISH EDITION
REVISED AND ENLARGED BY THE TRANSLATOR

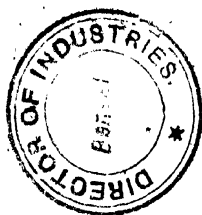
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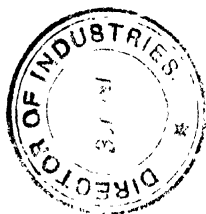


PREFACE TO THE SECOND ENGLISH EDITION.

THE original French treatise of M. Tailfer was in many ways a very excellent one. The reviser has attempted to present the subject matter with more logical sequence, and hopes that in the new edition the different arrangement of the chapters, several of which have been rewritten, or the subject matter collated into a single and more homogeneous one, will turn out to be an improvement. Moreover, the chemical terminology has been modernized. An entirely new chapter deals with SINGING, and another chapter, also new to the book, treats on the BLEACHING OF FABRICS BY PEROXIDES AND PERSALTS, whilst a third new chapter deals with the BLEACHING OF JUTE AND HEMP. Every chapter has been thoroughly revised, and several chapters have been enlarged and in great part rewritten. Lye-boiling by milk of lime has a separate chapter to itself. Several new illustrations of modern British and French bleaching machinery have been added. Unfortunately the time taken by the blocks for the French machinery in transit between Paris and London (July, 1914-October, 1915) delayed the printing of the book. May the trade receive it as favourably as it did the first edition! An entirely new and perhaps more serviceable index has been prepared.

THE TRANSLATOR AND REVISER.

LONDON, *June*, 1917.



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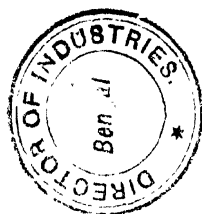
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THE VEHICLE FOR REAGENTS USED IN BLEACHING.

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ty of the Water—Testing the Water in the Boilers.*

DIFFERENT PLANT FOR PURIFICATION.—*Filters.*

THE quality of water is of great importance in bleaching, and the differences in the waters used often explains why bleach works which use the same process do not obtain equally beautiful whites. It is therefore preferable to discuss the question of water supply before that of site, and prior to describing the process and function of washing or bleaching. The importance of attending to this point of water supply at time of selecting the site will then be better understood. No site should be selected for a bleach works where an ample constant supply of suitable water is not available. Water is the raw material *par excellence* of the bleacher, and if he neglects the purity of his prime raw material he is blind to his own interests and making a false start at the outset. True, there are chemical processes in existence for correcting the nature of unsuitable waters.

Their application on a grand scale would entail in some instances too great an expense, but in certain more restricted cases it may be found very advantageous to purify the water—for example, the water used in soap scouring, or to feed the steam boilers. If the bleacher wishes to have a complete analysis of the water he is using, it is advisable to consult a chemist, because it requires instruments and experience which the ordinary bleacher does not generally possess. Some information as to the nature of different waters, and the drawbacks due to the saline matter which they contain in solution, will now be given, and at the same time instructions for some simple methods for the analysis of water and deducing therefrom the proportion in which the chemicals to be employed for its purification should be used. For more elaborate details see De la Coux's "Industrial Uses of Water" (Scott, Greenwood & Son).

Qualities of Water.—A. *Distilled Water.*—Of all waters this is the most free from impurities, and is especially to be preferred for effecting solution of the different chemical reagents employed in bleaching and for use *per se* in washing the fabric free, not only from the reagents themselves, but from the impurities liberated by the latter after each treatment with such reagents. The bleacher, dyer, or calico printer very often carries on quite a number of operations in the details of his various processes in the aggregation of different or detached buildings which constitute his factory. As the operations involve the use of extensive machinery and plant, the steam required to be generated as a motive power and for use as a source of heat for vessels heated by steam is very considerable. No very great engineering feat is necessary to condense the whole of the corresponding waste escape steam to distilled water available for all the purposes of the bleacher, nor to purify it from any oil with which it may be contaminated. Open steam cannot of course be recovered. Nor is it suggested that distilled water should be used for all operations in the bleach works, but for such delicate operations where its employment might be advisable.

B. *Soft (Rain) Water*.—Next in purity to distilled water comes rain water. Rain water is the best natural water which can be used for general bleaching purposes, because it does not contain lime salts and because it dissolves soap very freely. The rain as it falls from the clouds traverses the atmosphere, and in so doing becomes charged with soluble and insoluble matters. The soluble matters are the gases of the air—oxygen, nitrogen, and carbonic acid. There is always (1) a little ammonia, due to the decomposition of organic matters; (2) a little nitric acid, due to the action of electric discharges in the regions of the clouds on the mixture of oxygen and nitrogen; (3) ozone, due in the same way to the action of electricity on oxygen; finally (4) barely appreciable traces of mineral salts coming from the dust which the wind raises from the surface of the earth. The sodium chloride in rain water is air driven from the sea. The presence of some of these different bodies explains how rain water assists the bleaching of fabrics exposed on the grass. Organic matter, coal, and other dusts prevent the use of rain water on account of their soiling the fabrics; but if it be possible to collect it in cisterns and filter it through sand to get rid of the dust, a better natural water cannot be found.

C. *Soft (Terrestrial) Waters*.—Spring, river, lake, and pond waters consist of water which has been in contact with the earth for a greater or less time. They contain soluble substances derived from and peculiar to the particular ground which they have traversed. Waters are classified according to the nature of the salts and substances which they contain.

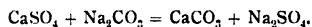
D. *Permanently Hard (Selenitic) Waters*.—Selenitic waters contain the greater part of their lime as sulphate. Such are the waters of the wells of Paris, Burton, etc., which are sometimes saturated with sulphate of lime. They do not become cloudy on boiling, but form abundant precipitates with ammonium oxalate and barium chloride.

They cannot be used for cooking vegetables because the lime present in such a large quantity combines with the vegetable casein or legumen of the envelope of haricot beans, peas,

and lentils, and this very hard calcareous compound does not soften on boiling. (Burton water excels for brewing.)

They do not dissolve soap readily, they first decompose it. Soap consists essentially of stearate of soda, which salts of lime convert into insoluble stearate of lime.¹ Soda lye forms, with the resinous or gummy matter of the fabrics, a kind of soluble soap, which the selenitic water decomposes in a manner analogous to that of soaps properly so called, and thus the object aimed at in washing—the removal of the substances dissolved by the lye—is not accomplished.

These waters may be rendered fit for industrial use and like purposes by the addition of carbonate of soda; carbonate of lime is formed, which precipitates, and sulphate of soda, which is comparatively harmless in small quantity, remains dissolved.



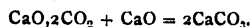
The presence of sulphate of lime is most manifest in those springs which issue from selenitic strata. The analysis of a Paris well showed it to contain 1·320 gramme of sulphate of lime per litre. According to analysis made at Lyons by Dupasquier and Seeligman, the water of several springs of that town used for potable purposes contained 0·25, 0·942, and even 1·15 gramme of sulphate of lime per litre. The water of streams and rivers contains a much smaller quantity, as is shown in the following table:—

Quantity of Sulphate of Lime per litre of Water.		
Water of the Seine	-	0·039 gramme.
„ Rhône	-	0·005 „
„ Saône	-	0·003 „
„ Loire	-	0·002 „

¹ The soaps so precipitated are struck on to the fibre, and if not removed, eventually show themselves after being naturally dehydrated, and the metallic element ferrous iron is oxidized in the course of time, or by steam heat; moreover, in addition, e.g. brown bone fat, these metallic soaps further stain the fabrics in proportion to the depth of colour of the raw ingredients from which the soap was made.—TR.

E. Temporarily Hard Waters.—Certain waters which have undergone greater pressure in the lower strata of the crust of the earth are charged with carbonic acid, and in their passage through calcareous rocks dissolve appreciable quantities of carbonate of lime as bicarbonate or acid carbonate. When they issue from the surface of the ground, the pressure diminishing, they lose carbonic acid and deposit carbonate of lime. The water of the stream of Saint-Allyre in Auvergne yields so abundant a deposit that an object plunged for several hours in that water becomes covered with a uniform solid layer of carbonate of lime. A similar phenomenon occurs with the waters of Matlock. Many deposits of carbonate or of phosphate of lime are formed by this method of slow precipitation. The encrustations deposited in conduit pipes by certain waters are produced in the same way. Calcareous waters turn a solution of logwood blue, turn cloudy on boiling, and on exposure to the air or under the influence of lime water precipitate the excess of carbonic acid. They may be rendered potable and fit for domestic and industrial purposes by the following processes :—

(1) Boiling, then setting at perfect rest and drawing off. There is thus disengagement of the free carbonic acid and the carbonic acid which formed the soluble bicarbonate, and the insoluble carbonate is precipitated under the form of a white powder. (2) Agitation in contact with air. This mechanical method accomplishes the same end as the preceding. (3) Treatment by lime water until that liquid gives no further precipitate. The following reaction then takes place :—



It is to the use of these unsoftened waters that the calcareous deposits of steam boilers are due. The hardness of the deposits is such that a hammer and chisel are required to detach them from the sides of the boiler. This cause of deterioration is remedied by introducing potato peelings, clay, ammonium chloride, or carbonate of soda into the water. These substances prevent the aggregation of the calcareous deposit and enable it to be easily removed afterwards. The bleacher

therefore who selects a site where the water is hard is seeking for trouble in the future, heavy coal bills due to encrustation in his boilers, or the possible lesser evil of heavy bills for chemicals to soften the water. He has to pay at every turn to remedy an evil which, by care in the selection of the site, might have been obviated at the outset.

F. *Mineral Waters*.—These are divided into seven classes, according to the nature of the predominating ingredient. (1) Alkaline waters contain alkaline bicarbonates. (2) Acidulated waters are characterized by the presence of carbonic acid gas. (3) Chlorinated waters contain sodium, potassium, or magnesium chlorides. (4) Sulphated waters are characterized by sulphate of magnesia or soda. (5) Sulphuretted waters contain alkaline sulphides. (6) Ferruginous waters owe their properties to the presence of iron. (7) Brominated and iodated waters contain alkaline bromides and iodides. Mineral waters are seldom met with, and only in certain districts, where their presence prevents the establishment of a bleach works. Ferruginous waters are more frequent; if they are highly charged with iron they are altogether unfit for bleaching purposes; if they only contain a small trace of iron the slight yellow coloration is removed by a hot sour with oxalic acid towards the end of the bleaching operations.

G. *River Water—Muddy Water. — Stagnant Water.* — Springs are generally limpid, and the deeper their source the less liable they are to be turbid. This is why they are preferred to the waters of rivers and ponds, even although they are often charged with calcareous principles. River water comes next in purity to rain water. When in its course it has drained a long expanse of peaty district, river water is often very dark in colour, especially when in flood, and owing to this colour being due to humic and ulmic acids, which would be struck on to the cloth in bleaching, such a water must be avoided. River water therefore is sometimes bright and at other times muddy from rain, when it contains more or less earthy matter in suspension, and possibly peaty matter in solution. In the latter case it is impossible to use it

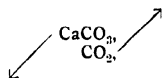
for washing fabrics, especially when they are nearly white. In those bleach works where only river water is available a filter is indispensable. It is equally necessary when the water—even spring water—contains in suspension substances which it has taken up from the rocks with which it has come in contact—ochres, for example, which dye the fabrics yellow. Stagnant water soon goes wrong in consequence of the development of lower organisms; they are injurious in domestic use, and are unsuitable for bleaching purposes, because they are not bright or because they communicate a bad smell to the fabrics. Rivers which drain a chalky country are apt to contain carbonate of lime in solution. This may have an injurious effect on delicate lake colours. Those which pass through a selenitic locality, e.g. Derbyshire, may be slightly charged with sulphate of lime, which would have the same injurious effect as the carbonate. The carbonate of lime may be eliminated by boiling (temporarily hard water). The sulphate of lime is not removed by boiling (permanently hard water).

Rapid Tests for Water.—A water in order to be more or less good for hygienic or industrial purposes ought to satisfy the following conditions. (1) It ought to be clear, bright, and limpid. (2) It ought to have no smell, and no disagreeable taste. (3) It should only leave a slight residue on evaporation. (4) It ought to dissolve soap well and form no curds with it. (5) It ought to cook vegetables without hardening them. (6) It should give no turbidity when tested with nitrate of silver (chlorides), nitrate of baryta (sulphates), or oxalate of ammonia (lime). These tests serve only to give a first indication of the value of a water. But more rigorous and precise methods must be adopted when submitting waters to a conscientious analysis.

Clark's Water-softening Process.—The late Professor Clark, of Aberdeen, was the first to use the soap test in a rational and scientific manner, and to elaborate from the data he obtained a thoroughly practical scheme for the softening and purification of water on the large scale. Both his method of

estimating the hardness of water, and his process for softening the same modified to meet special cases, continue to be identified with his name, but must not be confounded the one with the other, as an entirely different method of procedure is adopted in removing the hardness to that used in estimating it. Before considering this process somewhat in detail, it will be necessary to go a little more fully into the chemical principles involved in the answer to the query, why one water is soft and another hard, e.g. why, on the one hand the water supplied to Glasgow is as soft as rain water, whilst London water is, on the other hand, so hard that there is difficulty at first in producing a lather, especially in cold water, more particularly the deep-seated artesian well water from the chalk. Glasgow water falls as rain in a district consisting essentially of hard silicious insoluble rocks. The area on which it falls drains into Loch Katrine, from whence it is conveyed to Glasgow. It does not, therefore, from the time it falls as rain till it is supplied to the manufacturer or householder come in contact with rocks abounding in soluble saline matter in the same way as the Thames water supplied to London. The latter, falling on the Cotswold Hills, eventually traverses a district abounding in chalk, a loose, friable, impure, earthy limestone, consisting essentially of carbonate of lime. Carbonate of lime, a combination of calcium oxide (CaO) (quicklime) and carbonic acid CO_2 , may be represented by the symbols CaCO_3 . Carbonate of lime is practically insoluble in distilled water free from carbonic acid. But natural waters always contain this gas, derived partly from the aeration it undergoes in falling from a higher height to a lower level, or by the force with which it may strike against an obstacle; in such a case the carbonic acid is derived from the air. By the slow decomposition of vegetable matter in contact with water carbonic acid is also formed and absorbed. Water at the ordinary temperature and pressure can only take up carbonic acid (CO_2), but this is quite sufficient to enable the water in question to dissolve a certain proportion of carbonate of lime. A very limited amount of carbonic acid forms no

exception to the general rule that all gases dissolved in water at the ordinary temperature, which do not combine with it chemically, may be removed by boiling. The carbonate of lime held in solution by carbonic acid may be represented thus—



whilst on boiling, what goes on may be illustrated by the arrows as follows: CaCO_3 thrown out of solution; CO_2 goes off as gas. If a few ounces of clear lime water be breathed into for a short time all the lime is converted from the hydrated oxide into the carbonate, and if the breathing be continued, the milky precipitate of carbonate of lime finally dissolves, leaving the water as clear as it was originally; but if the water be boiled, so as to expel the excess of carbonic acid, then the carbonate of lime is again thrown out of solution. Moreover, if instead of boiling off the carbonic acid there be added to the clear solution an equal quantity of the original lime water, the excess of carbonic acid, which is keeping the carbonate of lime in solution, will combine with the fresh quantity of lime water to form carbonate of lime, and there being no excess of carbonic acid, it is consequently precipitated, but not only so, the carbonate of lime previously existing in solution is also precipitated. So complete is the precipitation that, if the experiment be done with care and precision, not a trace of lime need be found in solution. Clark's method of softening water is based upon that principle. Although it is very effectual in this respect, and although it should be adopted by every consumer of hard water on the large scale, nevertheless its employment is far from being universal, notwithstanding the fact that so efficient did this process prove in working on the large scale that so far back as 1851, eleven years from the date of Clark's patent, Professors Graham, Miller, and Hoffmann, reporting to the Government of the day as to the chemical quality of the waters supplied, or about to be supplied, to the Metropolis, asserted,

with reference to Clark's process: "It is no longer possible to disregard the chemical means of removing hardness, or to represent them as impracticable on a great scale; they place the question of water supply on an entirely new footing". The quality of the water submitted to Clark's softening process is always enhanced, never deteriorated; its suitability, whether for household or manufacturing purposes, is always greater, never less. It is difficult therefore to conceive why its adoption has not been more general; perhaps the seeming anomaly of adding lime to remove lime may have looked too paradoxical to water consumers not too well versed in the rudiments of chemistry. Moreover, in most text-books, the principle on which adding lime depends is only referred to in a passing way, or enunciated in an obscure manner. Be that as it may, it will at once be seen that the success of this process depends on the addition of just enough milk of lime, and no more, than will combine with the free carbonic acid to form free carbonate of lime, and simultaneously precipitate the carbonate of lime previously existing in solution. Any great excess of milk of lime over and above this, instead of ameliorating the water, would deteriorate it.

Lime Required for each 700 Gallons of Water per Part of Temporary Hardness in 100,000 Parts.—But, by previously submitting the water to what is known as Clark's soap test, the exact proportion of milk of lime to use with any given water may be adjusted to a nicety, or at least near enough for all practical purposes. According to Frankland, any water which softens on boiling for half an hour will be softened to an equal extent by Clark's process. He reckons that to soften 700 gallons of water, 18 oz. of quicklime would be required for each part of temporary hardness in 100,000 parts of water. The process, which is simplicity personified, consists in slaking the necessary quantity of freshly-burnt quicklime, and then stirring the whole well up in a pail of water immediately before it is poured into the cistern containing 50 gallons of the water to be softened, care being taken not to run in any grit which may have sunk to the bottom in the interval. The

pail is again filled with water, and the contents run into the cistern in the same way as before. The remainder of the 700 gallons is then run into the cistern in as great a rush as possible, so as to thoroughly incorporate the milk of lime with the whole bulk of the water. But if the rate of flow be too slow to effect this, then recourse must be had to mechanical agitation with a wooden paddle.

Cost.—The cost of treating one million gallons of chalk water in this way has been found to be as follows: 16 cwt. of lime, at £1 per ton, 16s. ; labour, 7s. ; total, £1 3s. One cwt. of quicklime is equally effective in this respect as 4½ cwt. of soda, or 20¼ cwt. of hard soap.

Water Decolorized.—It has also been noticed that, before softening, Thames water¹ has a brownish-yellow hue when viewed in bulk or mass, say in a tank four or five feet deep, owing to the presence of humic and ulmic matter in solution, but after being softened it exhibits the bluish-green cast of pure water, comparable, in fact, as asserted by Frankland, to that of the Rhone as it issues from the Lake of Geneva, the water of which, as he alleges, has been deprived of its colour in an analogous manner by agitation with the mud of the glaciers of the Rhone and Zermat valleys.

Standards of Water Hardness and their Determination.—At the outset, it is rather unfortunate that the analytical results obtained by the soap test for hard water are expressed by different countries in different ways. In Great Britain as grains of carbonate of lime per gallon, i.e. 1° equals 1 part of carbonate of lime in 70,000 parts of water. In France as milligrammes of carbonate of lime in 100 grammes of water, i.e. 1° equals 1 part carbonate of lime in 100,000 parts of water. In Germany as milligrammes of calcium oxide CaO (quicklime) in 100 grammes of water, i.e. 1° equals 1 part of quicklime in 100,000 parts of water.

¹ This, of course, does not apply to the dark muddy estuarine water of the Thames as it flows through London. Lime, however, acts chemically on many of the obnoxious or deleterious impurities in water and forces it from these as well as softens it.

COMPARATIVE TABLE OF DEGREES OF HARDNESS.

English.		German.		French.
0·7	=	0·56	=	1·0
1·0	=	0·8	=	1·43
1·25	=	1·0	=	1·79

1. *British Practice.—Preparation of Soap Solution.*—Make a lead plaster by digesting with frequent stirring 9 parts of *pure* olive oil and 5 parts of litharge, with a sufficiency of water in a porcelain basin on the water-bath, renewing the water from time to time as it evaporates. Digestion is continued until all oily globules have disappeared, and complete saponification has been effected, after which the mass is dried at 100° C. Grind up, little by little, in a porcelain mortar 3 parts of the plaster, made as above, with 1 part of pure dry potassium carbonate. When the two substances are thoroughly incorporated to a homogeneous mass, pour a little methylated spirit on to the mixture, and continue to triturate until the whole assumes the consistency of cream or liquid paint, after which it is allowed to stand overnight, and the clear supernatant solution of potash soap in alcohol is passed through a filter, and this process of trituration, digestion, and filtration is repeated until the residue cedes no more soap to the alcohol. The soap solution, which should be clear, is now titrated with a standard solution of calcium chloride, CaCl_2 .

2. *Preparation of Standard Calcium Chloride.*—Take a piece of the most pure white saccharine marble obtainable, pulverize very finely, and weigh out exactly 0·2 gramme into a porcelain basin, and dissolve in pure dilute hydrochloric acid, previously covering the dish with a watch glass, to prevent loss of material by its being carried away by the escaping carbonic acid. When this gas ceases to be evolved, wash all calcium chloride off the watch glass into the basin, and evaporate to *complete* dryness. Now redissolve in a small quantity of distilled water, and again evaporate to dryness, so as to completely expel any free hydrochloric acid, a result not so easily achieved as at first sight might be imagined. The

resulting calcium chloride should be quite neutral to test paper. If not, re-solution and re-evaporation must be resorted to. When perfectly neutral, the calcium chloride is dissolved in water, and the bulk made up to a litre.

3. *Titration and Standardizing of the Soap Solution.*—

Fifty cubic centimetres of the standard solution of calcium chloride are run into an accurately stoppered $\frac{1}{4}$ litre bottle. A burette is then filled with the soap solution, which is run therefrom, a few drops at a time, into the soap solution in the bottle, inserting the accurately fitting stopper, and shaking well after each addition, until a uniform lather results, which remains persistent after three minutes, and which may be regenerated by further shaking. The reading of the burette is now taken, and the soap solution is diluted with weak alcohol, 2 of methylated spirit to 1 of water, until 12 cubic centimetres or thereby equals 50 cubic centimetres of the standard calcium chloride solution, after which it is allowed to settle for twenty-four hours, and then filtered, if need be. Its strength is again determined, and then so adjusted—by addition of the dilute alcohol—that 14.25 cubic centimetres are exactly necessary to generate a permanent lather with 50 cubic centimetres of the standard solution of calcium chloride.

3a. *German Method of Standardizing Soap Solution.*—A lead plaster is prepared, as in the English method, and 150 parts thereof are incorporated with 40 parts of potassium carbonate, and the mass thoroughly exhausted with alcohol, and the latter distilled off, and the residue dissolved in the proportion of 20 to 1000 in dilute alcohol, specific gravity .9213. This solution is titrated and adjusted in the usual way with a solution of crystallized barium chloride ($\text{BaCl}_2 + 2\text{Aq}$) = 0.523 gramme per litre, so that 45 cubic centimetres of the soap solution equal 100 cubic centimetres of the barium chloride solution.

Saiszt and Knaus have pointed out that the degree of hardness (German) is not strictly proportional to the volume of soap solution, as will be seen from the following table:—

Soap Solution.	Degree of Hardness, German.	Difference for 1 c.c. of Soap Solution.	Soap Solution.	Degree of Hardness, German.	Difference for 1 c.c. of Soap Solution.
c.c.			c.c.		
3'4	0'5	0'25°	28'0	7'0	0'277°
5'4	1'0		29'8	7'5	
7'4	1'5		31'6	8'0	
9'4	2'0		33'3	8'5	
11'3	2'5		35'0	9'0	
13'2	3'0	0'26°	36'7	9'5	0'294°
15'1	3'5		38'4	10'0	
17'0	4'0		40'1	10'5	
18'9	4'5		41'8	11'0	
20'8	5'0		43'4	11'5	
22'6	5'5	0'277°	45'0	12'0	0'31°
24'4	6'0				
26'2	6'5				

3b. *French Method of Standardizing Soap Solution.*—White Marseilles soap, 50 grammes; alcohol 90°, 800 grammes. The soap is cut into thin slices, and dissolved in the alcohol by heating on the water-bath. When complete solution is effected, the liquid is filtered, and 500 cubic centimetres of distilled water added thereto. The soap solution is then titrated and adjusted so that forty-three divisions of a special burette give a persistent lather with 40 cubic centimetres of a standard solution of calcium chloride containing 0'25 gramme per litre.

The following table shows the ratio between 1° of hardness (French) and the corresponding salt to which the hardness is due:—

	1° equals in Grammes per litre.
Lime (CaO) - - - -	0'0057
Calcium chloride (CaCl ₂) - - - -	0'0114
Carbonate of lime (CaCO ₃) - - - -	0'0103
Sulphate of lime (CaSO ₄) - - - -	0'0140
Magnesia (MgO) - - - -	0'0042
Magnesium chloride (MgCl ₂) - - - -	0'0090
Magnesium carbonate - - - -	0'0080
Magnesium sulphate (MgSO ₄) - - - -	0'0125

					1° equals in Grammes per litre.
Sodium chloride (NaCl)	-	-	-	-	0·0120
Sodium sulphate (Na ₂ SO ₄)	-	-	-	-	0·0146
Sulphuric acid	-	-	-	-	0·0082
Chlorine	-	-	-	-	0·0075
Soap (50 per 100 of water)	-	-	-	-	0·1061
Carbonic acid	-	-	-	-	0 lit. '005

4. *Determination of Hardness — British Method.*— Fifty cubic centimetres of the water to be tested are drawn off, and run into the 250 cubic centimetres bottle, which is then stoppered and well shaken, after which the air is sucked out by means of a piece of glass tubing, so as to eliminate all the carbonic acid expelled from the water by the previous shaking. The burette is now filled up with the soap solution, and run into the water 1 cubic centimetre at a time, the stopper inserted, and the bottle well shaken after each addition. Under no circumstances should the soap solution be added in bulk, not even when the hardness is approximately known. When a foam or froth commences to be generated, the soap solution is run in, in less and less quantities, until a persistent homogeneous lather results. Should the water be so hard that more than 16 cubic centimetres of soap solution are used up in forming a persistent lather, the experiment must be repeated on a smaller quantity of the water, diluted with distilled water. Run in 25 cubic centimetres, or even a smaller quantity should the water be very hard, and make up to 50 cubic centimetres with distilled water, and then run in the soap solution, as before, until a persistent lather results. Multiply the number of cubic centimetres used up by the aliquot part of 50, which the volume of water taken represents. Thus, if 12½ cubic centimetres were taken, the result must be multiplied by 4, if 15 cubic centimetres by 3½, 20 cubic centimetres by 2½, 25 cubic centimetres by 2, and so on.

The lather produced by waters abounding in salts of magnesia is of a typical light curdy nature, which the operator

may easily differentiate from that produced by lime salts by comparing the results obtained by running in the soap solution into the calcium chloride solution, and at the same time treating a solution of magnesium sulphate of a strength equal to that of the calcium chloride in a similar manner.

Should a preliminary test demonstrate that magnesium salts be present in rather large quantities, before performing the operation the water to be tested should be diluted with distilled water, so that 50 cubic centimetres of the mixture should only need 6 to 7 cubic centimetres of the soap solution, as previously indicated. The total hardness of the water is determined on the original water, the permanent hardness on the water after boiling, whilst the difference between the two determinations gives the temporary hardness. Should the hardness be less than 3 parts per 100,000, it does not decrease on boiling, as the carbonates of lime, magnesia, etc., are soluble to that amount in water free from carbonic acid.

Determination of Permanent Hardness.—Run in 200 cubic centimetres of the water into a flask, boil gently for half an hour, allow all steam to escape, as any condensing and falling back would redissolve the escaping carbonic acid.

Details of French Method of Determining the Degree of Hardness (Hydrotimetry).—The description of this method is taken from Olive's "Course of Hydraulics". The solid substances in fresh water consist almost exclusively of salts of lime and magnesia. The other substances present are found in barely appreciable quantities. It is sufficient, therefore, to determine the former, which is done by estimating the hardness. This process is based upon the property, which soap possesses, of giving a persistent lather with distilled water, whilst calcareous or dolomitic (magnesian) waters give no lather until all their salts have been precipitated as stearates, etc., of lime or magnesia. This point being established, if soap be dissolved in alcohol and poured drop by drop into a calcareous water, no lather is produced until the calcareous salt has decomposed a corresponding quantity of soap. To ascertain the richness of the water in calcareous salts, all that is

WATER HARDNESS.

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HARDNESS TABLE.

A		B		A		B		A		B		A		B		A		B		A		B	
C.C.		C.C.		C.C.		C.C.		C.C.		C.C.		C.C.		C.C.		C.C.		C.C.		C.C.		C.C.	
0.7	8	0.3	16	3.3	4	3.64	7.29	8.5	6	11.05	11.1	13.7	8	15.00	19.13	13.7	8	15.00	19.13	13.7	8	15.00	19.13
8	9	.32	.48	4	.90	.77	.43	6	.20	.35	2	9	.32	.48	.29	9	.32	.48	.29	9	.32	.48	.29
9	10	.48	.63	5	1.00	1.03	.57	7	.30	.50	3	14.0	.48	.63	.44	14.0	.48	.63	.44	14.0	.48	.63	.44
10	1	.63	.79	6	1.21	1.21	.71	8	.40	.60	4	16.0	.63	.79	.76	16.0	.63	.79	.76	16.0	.63	.79	.76
1	2	.79	1.11	7	1.44	1.44	.86	9	.50	.80	5	18.0	.79	1.11	.92	18.0	.79	1.11	.92	18.0	.79	1.11	.92
2	3	1.11	1.44	8	1.69	1.69	1.00	10	.60	1.00	6	20.0	1.11	1.44	20.0	1.11	1.44	20.0	1.11	1.44	20.0	1.11	1.44
3	4	1.44	1.77	9	1.96	1.96	1.21	11	.70	1.21	7	22.0	1.44	1.77	.24	22.0	1.44	1.77	.24	22.0	1.44	1.77	.24
4	5	1.77	2.11	10	2.25	2.25	1.44	12	.80	1.44	8	24.0	1.77	2.11	.40	24.0	1.77	2.11	.40	24.0	1.77	2.11	.40
5	6	2.11	2.44	11	2.56	2.56	1.69	13	.90	1.69	9	26.0	2.11	2.44	.56	26.0	2.11	2.44	.56	26.0	2.11	2.44	.56
6	7	2.44	2.77	12	2.89	2.89	1.96	14	1.00	1.96	10	28.0	2.44	2.77	.71	28.0	2.44	2.77	.71	28.0	2.44	2.77	.71
7	8	2.77	3.11	13	3.24	3.24	2.25	15	1.10	2.25	11	30.0	2.77	3.11	.86	30.0	2.77	3.11	.86	30.0	2.77	3.11	.86
8	9	3.11	3.44	14	3.61	3.61	2.56	16	1.21	2.56	12	32.0	3.11	3.44	.92	32.0	3.11	3.44	.92	32.0	3.11	3.44	.92
9	10	3.44	3.77	15	3.89	3.89	2.89	17	1.30	2.89	13	34.0	3.44	3.77	.98	34.0	3.44	3.77	.98	34.0	3.44	3.77	.98
10	11	3.77	4.11	16	4.00	4.00	3.24	18	1.40	3.24	14	36.0	3.77	4.11	1.04	36.0	3.77	4.11	1.04	36.0	3.77	4.11	1.04
11	12	4.11	4.44	17	4.41	4.41	3.61	19	1.50	3.61	15	38.0	4.11	4.44	1.10	38.0	4.11	4.44	1.10	38.0	4.11	4.44	1.10
12	13	4.44	4.77	18	4.84	4.84	4.00	20	1.60	4.00	16	40.0	4.44	4.77	1.16	40.0	4.44	4.77	1.16	40.0	4.44	4.77	1.16
13	14	4.77	5.11	19	5.00	5.00	4.41	21	1.70	4.41	17	42.0	4.77	5.11	1.22	42.0	4.77	5.11	1.22	42.0	4.77	5.11	1.22
14	15	5.11	5.44	20	5.29	5.29	4.84	22	1.80	4.84	18	44.0	5.11	5.44	1.28	44.0	5.11	5.44	1.28	44.0	5.11	5.44	1.28
15	16	5.44	5.77	21	5.61	5.61	5.29	23	1.90	5.29	19	46.0	5.44	5.77	1.34	46.0	5.44	5.77	1.34	46.0	5.44	5.77	1.34
16	17	5.77	6.11	22	6.00	6.00	5.77	24	2.00	6.00	20	48.0	5.77	6.11	1.40	48.0	5.77	6.11	1.40	48.0	5.77	6.11	1.40
17	18	6.11	6.44	23	6.49	6.49	6.25	25	2.10	6.49	21	50.0	6.11	6.44	1.46	50.0	6.11	6.44	1.46	50.0	6.11	6.44	1.46
18	19	6.44	6.77	24	6.76	6.76	6.76	26	2.20	6.76	22	52.0	6.44	6.77	1.52	52.0	6.44	6.77	1.52	52.0	6.44	6.77	1.52
19	20	6.77	7.11	25	7.00	7.00	7.29	27	2.30	7.29	23	54.0	6.77	7.11	1.58	54.0	6.77	7.11	1.58	54.0	6.77	7.11	1.58
20	21	7.11	7.44	26	7.29	7.29	7.77	28	2.40	7.77	24	56.0	7.11	7.44	1.64	56.0	7.11	7.44	1.64	56.0	7.11	7.44	1.64
21	22	7.44	7.77	27	7.56	7.56	8.25	29	2.50	8.25	25	58.0	7.44	7.77	1.70	58.0	7.44	7.77	1.70	58.0	7.44	7.77	1.70
22	23	7.77	8.11	28	7.96	7.96	8.84	30	2.60	8.84	26	60.0	7.77	8.11	1.76	60.0	7.77	8.11	1.76	60.0	7.77	8.11	1.76
23	24	8.11	8.44	29	8.25	8.25	9.44	31	2.70	9.44	27	62.0	8.11	8.44	1.82	62.0	8.11	8.44	1.82	62.0	8.11	8.44	1.82
24	25	8.44	8.77	30	8.56	8.56	10.00	32	2.80	10.00	28	64.0	8.44	8.77	1.88	64.0	8.44	8.77	1.88	64.0	8.44	8.77	1.88
25	26	8.77	9.11	31	8.89	8.89	10.59	33	2.90	10.59	29	66.0	8.77	9.11	1.94	66.0	8.77	9.11	1.94	66.0	8.77	9.11	1.94
26	27	9.11	9.44	32	9.00	9.00	11.16	34	3.00	11.16	30	68.0	9.11	9.44	2.00	68.0	9.11	9.44	2.00	68.0	9.11	9.44	2.00
27	28	9.44	9.77	33	9.21	9.21	11.75	35	3.10	11.75	31	70.0	9.44	9.77	2.06	70.0	9.44	9.77	2.06	70.0	9.44	9.77	2.06
28	29	9.77	10.11	34	9.44	9.44	12.36	36	3.20	12.36	32	72.0	9.77	10.11	2.12	72.0	9.77	10.11	2.12	72.0	9.77	10.11	2.12
29	30	10.11	10.44	35	9.69	9.69	12.97	37	3.30	12.97	33	74.0	10.11	10.44	2.18	74.0	10.11	10.44	2.18	74.0	10.11	10.44	2.18
30	31	10.44	10.77	36	9.96	9.96	13.60	38	3.40	13.60	34	76.0	10.44	10.77	2.24	76.0	10.44	10.77	2.24	76.0	10.44	10.77	2.24
31	32	10.77	11.11	37	10.25	10.25	14.25	39	3.50	14.25	35	78.0	10.77	11.11	2.30	78.0	10.77	11.11	2.30	78.0	10.77	11.11	2.30
32	33	11.11	11.44	38	10.56	10.56	14.89	40	3.60	14.89	36	80.0	11.11	11.44	2.36	80.0	11.11	11.44	2.36	80.0	11.11	11.44	2.36
33	34	11.44	11.77	39	10.89	10.89	15.56	41	3.70	15.56	37	82.0	11.44	11.77	2.42	82.0	11.44	11.77	2.42	82.0	11.44	11.77	2.42
34	35	11.77	12.11	40	11.21	11.21	16.25	42	3.80	16.25	38	84.0	11.77	12.11	2.48	84.0	11.77	12.11	2.48	84.0	11.77	12.11	2.48
35	36	12.11	12.44	41	11.56	11.56	16.96	43	3.90	16.96	39	86.0	12.11	12.44	2.54	86.0	12.11	12.44	2.54	86.0	12.11	12.44	2.54
36	37	12.44	12.77	42	11.89	11.89	17.69	44	4.00	17.69	40	88.0	12.44	12.77	2.60	88.0	12.44	12.77	2.60	88.0	12.44	12.77	2.60
37	38	12.77	13.11	43	12.25	12.25	18.44	45	4.10	18.44	41	90.0	12.77	13.11	2.66	90.0	12.77	13.11	2.66	90.0	12.77	13.11	2.66
38	39	13.11	13.44	44	12.56	12.56	19.21	46	4.20	19.21	42	92.0	13.11	13.44	2.72	92.0	13.11	13.44	2.72	92.0	13.11	13.44	2.72
39	40	13.44	13.77	45	12.89	12.89	19.96	47	4.30	19.96	43	94.0	13.44	13.77	2.78	94.0	13.44	13.77	2.78	94.0	13.44	13.77	2.78
40	41	13.77	14.11	46	13.25	13.25	20.75	48	4.40	20.75	44	96.0	13.77	14.11	2.84	96.0	13.77	14.11	2.84	96.0	13.77	14.11	2.84
41	42	14.11	14.44	47	13.56	13.56	21.56	49	4.50	21.56	45	98.0	14.11	14.44	2.90	98.0	14.11	14.44	2.90	98.0	14.11	14.44	2.90
42	43	14.44	14.77	48	13.89	13.89	22.36	50	4.60	22.36	46	100.0	14.44	14.77	2.96	100.0	14.44	14.77	2.96	100.0	14.44	14.77	2.96

Column A = Number of cubic centimetres to produce permanent lather.

Column B = Parts of carbonate of lime in 100,000 parts of water. To convert into Clark's degrees, or grains, per gallon, multiply by 0.7.

required is a standard solution of soap. The method of working is as follows :—

A standard solution of soap is made by dissolving 50 grammes of white Marseilles almond oil soap in 800 grammes of 90 per cent alcohol. The solution thus obtained is filtered and 500 grammes of distilled water added. There is thus obtained 1350 grammes of test liquor. The test liquor made in this way contains in solution $\frac{1}{4000}$ of its weight of calcium chloride, say 0.25 gramme of this salt per litre. It is moreover tested to ascertain its real strength. A quantity of the liquid equal to 2.4 cubic centimetres is run into a hydrotimetric burette of a total capacity of 7 cubic centimetres, and the space occupied by the 2.4 cubic centimetres is divided into twenty-three divisions.

The test liquor is of such a strength that twenty-two of these divisions contain sufficient soap solution to neutralize 1 centigramme of calcium chloride. The No. 0 of these divisions, placed at the top of the burette, is not marked opposite to the first division, but to the second. It has been found, in fact, that the quantity of soap solution corresponding to this first division is necessary to produce a permanent lather in 40 cubic centimetres of distilled water. Below 22° the burette is marked in equal divisions. Twenty-two of these divisions correspond to 1 centigramme of calcium chloride; each division, termed hydrotimetric, corresponds to a weight of calcium chloride equal to $\frac{0.01}{22}$. As the test is always performed on 40 cubic centimetres, that is on the $\frac{1}{25}$ of a litre, each hydrotimetric degree of soap solution used by these 40 cubic centimetres will represent a quantity of calcium chloride twenty-five times greater per litre. The test made on 40 cubic centimetres represents therefore for each hydrotimetric degree a weight of calcium chloride per litre equal to $\frac{0.01}{22}$ gramme $\times 25 = 0.0114$, say 0.01 gramme of carbonate of lime for the same quantity of water. It suffices, therefore, in order to ascertain the richness of a water in calcareous salts (supposed in the condition of calcium chloride), to multiply by 0.0114 the number of hydrotimetric degrees consumed by 40 cubic

centimetres of the water to be tested. As the molecular weights of calcareous salts are not very different, it can be taken for granted with sufficient exactitude for practical purposes that the analyses indicate the quantity of calcareous and magnesian salts whatever they may be. Thus a water which tests 28 hydrotimetric degrees contains 0.23 to 0.24 gramme of calcareous salts per litre. The hydrotimetric apparatus of Boutron and Boudet, who were the first to use this method, originally due to Clark, consists of: (1) A hydrotimetric or graduated burette constructed in such a manner that the circular mark at the top of the instrument shows the point to which it should be filled. The division included between this circular mark and the 0° represents the quantity of liquor required to produce a lather with distilled water. The hydrotimetric degrees start from the 0°. (2) A test bottle of 60 cubic centimetres capacity and graduated at 10, 20, 30, 40 cubic centimetres by circular marks. (3) A bottle of standard soap solution for hardness of water. (4) A flask of distilled water. The above suffice for the generality of tests, but if it be desired to push the analysis further, and determine according to the Boutron and Boudet process the carbonic acid of the salts of lime and magnesia and the proportion of sulphuric acid in the condition of sulphate contained in the water, the apparatus ought to include besides: (5) A bottle of ammonium oxalate solution (1 in 60). (6) A flask of nitrate of baryta titrated to 20° for 1 cubic centimetre. (7) A pipette divided into tenths of cubic centimetres. (8) A graduated flask. (9) Various accessories.

Hydrotimetric Test.—In order to test any water, 40 cubic centimetres is measured into the test bottle and the standard soap solution gradually added, testing from time to time to ascertain if a persistent lather be produced. The lather ought to form on the surface of the liquid a regular layer of more than $\frac{1}{2}$ centimetre in thickness and to maintain itself for at least ten minutes without disappearing. The degree read upon the hydrotimeter when this lather has been obtained is the hydrotimetric degree of the water examined. This degree indicates:—

1. The number of decigrammes of soap which this water neutralizes per litre.

2. The measure of purity or place which it occupies in the hydrotimetric scale.

For example, if the number 19 be read off, it results that a litre of the water tested neutralizes 19 decigrammes of soap, and that this water bears 19 as its number on the hydrotimetric scale.

The following table gives the hydrotimetric standard of several spring and river waters :—

Kind of Water.	Hydrotimetric Degree.	Quantity of Soap decomposed before a persistent lather is produced in one cubic metre of water. ¹
		Kilogrammes.
Distilled - - - -	0'0	0
Snow - - - -	2'5	0'250
Rain - - - -	3'5	0'350
L'Allier - - - -	3'5	0'350
La Dordogne - - -	4'5	0'450
La Garonne - - -	5'0	0'500
La Loire - - - -	5'5	0'550
La Somme (soda) - -	13'5	1'350
Le Rhône and La Saône -	15'0	1'500
L'Yonne - - - -	15'5	1'550
La Seine - - - -	17'0	1'700
La Marne - - - -	23'0	2'300
La Dhuis - - - -	23'0	2'300
L'Escout - - - -	24'0	2'400
L'Escout - - - -	24'5	2'450
Belleville - - - -	128'0	12'800

According to this table it will be seen, e.g., that water of 24 hydrotimetric degrees be used for soap scouring, 2'4 kilogrammes of soap per cubic metre of water, 5'28 lb. per 100 gallons are required to precipitate the salts in solution, and it is only the soap added over and above this amount that produces any useful effect in soap scouring.

The processes, the description of which has just been given, suffice in the majority of cases to decide whether a water is more or less pure. Boutron and Boudet have completed their process by applying it to the exact determination of the pro-

¹ Kilogrammes per cubic metre equal lb. per 100 gallons.—Tr.

portion of carbonate of lime, sulphate of lime, and other calcareous salts, salts of magnesia and carbonic acid contained in the water to be analysed. The following, according to them, is the method to pursue. The degree of hardness, hydrotimetric degree of the water, is determined: (1) In the natural state. (2) After precipitation of the lime by ammonium oxalate. (3) After eliminating the carbonic acid and the carbonate of lime by boiling. (4) After precipitating by ammonium oxalate the salts of lime *not* removed by boiling. Knowing the degrees of hardness in the natural state, 2 cubic centimetres of a $\frac{1}{80}$ solution of ammonium oxalate are added, the whole well stirred and let settle for half an hour, after which the water is filtered and thus freed from lime salts. The degree of hardness, hydrotimetric degree, is determined on 40 cubic centimetres of this water.

Example.—Suppose that 26° of hardness, hydrotimetric degrees, have been found in the first operation in the natural state and 9° in the second test. A fresh quantity of the water to be analysed is taken and boiled gently for half an hour, to precipitate lime and expel the carbonic acid. After cooling, distilled water is added to bring the water back to its original volume; the whole is well mixed and filtered; then the degree of hardness of 40 cubic centimetres of the filtered liquid is determined, say, for example, that 13° is the figure found. Then to 50 cubic centimetres of the previously boiled and filtered liquid 2 cubic centimetres of $\frac{1}{80}$ ammonium oxalate solution are added to expel the lime existing as carbonate which has not been expelled by boiling. After being allowed to stand and then filtered, the hardness is again determined on 40 cubic centimetres of the liquid, say, for example, that 7° is the figure found. As carbonate of lime is soluble in water, it is not entirely precipitated by boiling in the third operation; it is therefore necessary to correct the degree of hardness obtained after boiling. This correction consists in deducting the constant 3 from that figure, which will give in the present instance $13^{\circ} - 3^{\circ} = 10^{\circ}$.

From the readings previously made the following conclu-

sions are drawn : the first hydrotimetric degree, read off 26° , indicates that carbonic acid, salts of lime (carbonates, etc.), and of magnesia contained in the litre of water are neutralized by 26 decigrammes of soap. The second degree, read off 9° , indicates the salts of magnesia and carbonic acid remaining in the water after elimination of the lime ; therefore $26^{\circ} - 9^{\circ} = 17^{\circ}$ gives by difference the proportion of the hardness due to salts of lime. The third figure which, after correction, is 10° , represents the salts of magnesia and the salts of lime other than the carbonate ; therefore $26^{\circ} - 10^{\circ} = 16^{\circ}$ gives by difference the proportion of the hardness due to carbonate of lime and carbonic acid. Finally, the fourth degree, 7° , indicates the salts of magnesia which have been left untouched by boiling with ammonium oxalate. By adding together the degrees of hardness due to salts of lime and magnesia, say $17^{\circ} + 7^{\circ} = 24^{\circ}$, it will be seen that in the 26° of hardness in the natural water only 2° are due to carbonic acid. The water tested contains therefore in hydrotimetric degrees :—

Free carbonic, $26^{\circ} - 24^{\circ} = 2^{\circ}$.

Carbonate of lime, $16^{\circ} - 3^{\circ} = 13^{\circ}$.

Sulphates of lime and magnesia, $17^{\circ} - 13^{\circ} = 4^{\circ}$.

Salts of magnesia, 7° .

The table given on pages 14, 15 gives the equivalent in weight of a certain number of simple and compound bodies. By that table the weight of the salts found may be calculated from the hydrotimetric degrees yielded by the water tested.

Example.—In the preceding analysis the degree of hardness due to carbonic acid was found to be 2° ; all that is required to be done is to multiply this number by 0.005 litre of the preceding table : thus $2 \times 0.005 = 0.010$ litre of free CO_2 . The hardness due to carbonate of lime, 13° , will give in weight $13 \times 0.0103 = 0.133$ gramme. Hardness due to sulphate of lime, $4 \times 0.0140 = 0.056$. Hardness due to sulphate of magnesia, $7 \times 0.0125 = 0.0875$.

Owing to the small amount of hardness due to carbonic acid, it will be seen from the foregoing that the hydrotimetric

degree of a water represents approximately the weight in decigrammes of the earthy salts which it contains.

Dervaux Water Softener and Purifier.—This system of purifying and softening water consists in mixing—in proportions regulated according to its composition—by means of a distributing apparatus, the water to be purified, arriving by the pipe, with a saturated solution of milk of lime, produced in a saturating apparatus, and if need be with soda or other liquid reagent, and then causing the mixture to traverse a decanting apparatus, from which it issues purified by the tubulure.

Distributing Apparatus.—The water to be purified arrives through the valve into the distributing reservoir, from whence it runs into a decanting tank by a pipe, and issues from it by another pipe, traversing first from below upwards a saturator from whence it issues saturated with lime by the tubulure.

A solution of carbonate of soda is generally required for purification, in addition to a saturated solution of lime water. The necessary quantity of this additional reagent is dissolved in the reservoir. The reservoir feeds, by keeping it at a constant level with a solution of carbonate of soda, a small tank with float, equal in height to the reservoir. A movable out-flow tube is attached to the bottom of the reservoir, and is suspended by its free extremity, pierced by an exit orifice calibrated to the float floating on the water of the reservoir. The object of this arrangement is to stop the flow of the soda simultaneously with that of the reservoir. Moreover, the flows from the two tanks under the same charge of water are always in constant ratio.

If another reagent, such as persulphate of iron, requires to be used in the purifier, a second dissolving tank and a second distributing reservoir for distributing this reagent is naturally employed.

Saturator.—The object of the saturator is to transform a part of the water to be purified into saturated lime water, and to mix it with the other part to purify it. Clear, saturated lime water contains 1.23 gramme of quicklime per litre. The

Dervaux Cone Saturator is a vessel with an elongated conical bottom traversed from below upwards by the water to be saturated, which, as it flows in, is carried to the bottom of the saturator by the tube. Each day the charge of lime is run into the hopper, where it slakes in contact with the water, and by stirring it up therewith it is forced down the cone. The bottom of the cone being sufficiently acute, the current of water flowing in by the tube passes from below upwards and keeps the lime in suspension as milk of lime. The milk of lime thus formed rises slower and slower from the acute bottom towards the upper and gradually wider part of the cone, where, owing to the slackening of the speed of ascension, the lime in suspension separates from the water and falls back, and is conducted down the inclined sides to the bottom of the saturator into the water which runs in there by the tube which carries it up again, and so on until thoroughly exhausted. The saturated lime water issues clear from the saturator through the tube, after having circulated through the partitions in the form of inverse cones between which the clarification is effected.

Decanter.—The mixture of water to be purified and of saturated lime water is spread over the surface decanter in the reaction chamber, and descends slowly until the reactions have been completed before reaching the decanting surfaces. It results, therefore, that the flocculent precipitate, which forms as soon as the water to be purified and the reagent come together on the surface of the decanter, traverses the mass of descending water, bringing in its throes the final precipitates formed up to the completion of the reaction. The water afterwards rises slowly between the compartments of the decanter formed by superimposed cones, between which it divides into so many small ascending currents; the matter in suspension is deposited, and clear water reaches the orifice of the collecting pipe of the exit. If the decantation be not sufficient, the water is made to pass through a filter of wooden shavings, which stops any particles of carbonate of lime which the water may still contain.

Testing the Purified Water.—In order to make rapid tests, dropping bottles have been substituted for graduated burettes, and it is presumed that the drops have always the same volume. Instead of counting how many divisions of the burette are run in the number of drops is counted. The orifice of the dropping bottle is such that it requires four drops to make a volume of one-tenth of a cubic centimetre.

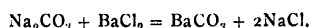
Necessary Apparatus.—It consists of: a dropping bottle of standard soap solution; a dropping bottle of decinormal test acid (acidulated phenolphthalein); test bottle graduated from 5 to 20 grammes; a reagent bottle containing solution of barium chloride, 100 grammes of dry barium chloride to the litre of distilled water.

Testing the Lime Water.—Lime water prepared in the following manner is run into the graduated bottle: two or three handfuls of powdered slaked lime, such as would be used for saturation, are run into a litre of water. The lime is mixed in such a manner as to saturate the water with it; it is then allowed to settle, and when the liquid is clear the graduated bottle is filled with it to the 5 gramme mark. Into the saturated lime water prepared in this way the test acid is poured, drop by drop, from the acidulated phenolphthalein bottle, until a red coloration, at first produced, suddenly disappears. The number of drops is counted. The same result should be produced when the test is made on the lime water of the saturator. The lime water being saturated the decoloration ought always to be produced with the same number of drops. If the decoloration be produced sooner, that would prove that the saturator is in want of lime.

Testing the Purified Water.—An hour or so after the lime saturator has been acting properly, the graduated bottle is filled to the 10 gramme mark; there is then run in, drop by drop, the standard soap solution until a light persistent lather is obtained, which must not be confounded with the froth which a bright water gives. The number of drops, less one, which it is necessary to pour into the water to get this lather represents the hydrotimetric degree of the purified

water. Working in good condition this degree ought to range from 4 to 6.

Testing the Alkalinity of the Water.—The graduated bottle is filled to the 10 gramme mark with the purified water, and one drop of the acidulated phenolphthalein run in from the reagent bottle, fitted with its dropping stopper, and the bottle shaken. The water ought to become slightly reddish, but it ought to be decolorized when a second drop is added. If the water is not coloured red by one drop there is a deficiency of reagents, and it is then necessary to force slightly both the lime water through the saturator and the quantity of carbonate of soda. If the water be coloured by the first drop, and be not decolorized by the second drop, it is because there is an excess of alkali in the water, either on account of too much lime or too much carbonate of soda. In order to see which of the two is in excess, barium chloride is added to the coloured liquid until the 20 gramme mark is reached, and the whole shaken. If the liquid be decolorized, carbonate of soda is in excess, because the barium chloride causes the alkaline reaction due to the carbonate of soda to disappear.



The flow of the carbonate of soda must then be diminished. If the liquid be not decolorized it is on account of an excess of caustic soda or an excess of lime, and in both cases the flow of water towards the saturator must be diminished. It is easy to ascertain which of the two is in excess, lime or soda, according to the degree of hardness of the water, which will be very low if soda be in excess. By means of these tests water of a sufficient degree of purity is obtained.

Testing of Water in the Boilers.—(1) The first thing that requires attention is to see that the water fed into the boilers is quite clear. This is verified by running some of the water into a clean clear glass, and observing whether any particles of lime remain in suspension. (2) Water is taken from the gauge glass, and after blowing off for a long time it is collected in a glass, and the test bottle filled with it to the 10 gramme mark, then the standard soap solution is added, drop by drop ;

a lather should not be obtained before the third or fourth drop, otherwise it will be necessary to diminish the quantity of carbonate of soda used in the purification of the water. If it requires more than three drops of soap to make a lather with the boiler water, that shows that the purified water wants carbonate of soda. On the other hand, if 10 grammes of the water are run into the test bottle, and chloride of barium added until the 20 gramme mark is reached, this water ought to be coloured by one drop of the acidulated phenolphthalein, and ought not to be decolorized before the sixth or eighth drop, otherwise more lime must be run into the saturator. This last test shows that there ought to be in the water a slight excess of caustic soda.

Various Purifying Arrangements.—The Dervaux purifier has been described to illustrate the order of ideas in which water purifiers are conceived, and this type has been chosen because the author, Telfer, saw it work successfully. Various other plans may be conceived. But the process of purifying may be summed up in the mixing of the water to be purified in suitable proportions with reagents which render soluble salts in the water insoluble, and afterwards in separating from the water the precipitates formed. The decanters have been conceived with the view of dividing the water into thin sheets and causing them to traverse the longest possible road so that they may abandon, in their passage, all suspended matter. Whatever arrangements may have been adopted for this purpose they are all more or less defective, and no system is superior to that of wide-surfaced reservoirs where the water decants slowly. An arrangement, adopted by Alfred Motte of Roubaix, provides for the mixture of the water to be saturated and the reagents being effected by a Dervaux saturator, and the decantation being effected in vast basins. The quantity of water purified is 2500 cubic metres and upwards daily.

Filters.—The decanters are often unable to eliminate the substances suspended in the matter and filters must be resorted to. They are used to clarify the muddy water of rivers, or to

retain the precipitates produced by chemical action. If the volume of water to be filtered is not considerable, filters of charcoal, sponges, or shavings may be used. At the end of a certain time the filters are saturated by the substances which they retain; they become choked and no longer pass water, or, on the other hand, the water in passing through the filter carries with it the deposits left there by other waters in their passage. Frequent cleansings are necessary. In order to filter large quantities of water it is preferable to adopt an arrangement analogous to that about to be described. An excavation is made in the ground 10 feet deep, in the form of a truncated cone. The sides are maintained by wooden flooring boards behind which piles are driven in. The whole is rammed all around and a layer of clay is laid in the bottom 12 inches in thickness to retain the water and separate it from the subsoil water. The filter bed is made as follows: (1) A layer of flat stones not joined together, where the water may make a start in depositing. A flush of water will eliminate from time to time the deposits so as to prevent the filter from choking up. (2) A layer of very fine sand of a thickness of 20 inches. (3) A layer of gravel of thickness of 20 inches. (4) A bed of small pebbles of thickness 6 inches. (5) A layer of shingle (stones) of 3 to 4 inches in diameter of thickness of 12 inches. (6) A layer of bricks pierced with small holes and supported on other bricks laid quincunx fashion so as not to impede the flow of the water towards the centre. The clarified water falls into an empty space of 12 inches in depth, from which it runs into a central well, from which it is lifted by a pump.

N.B.—Most of those firms who make water-softening plant supply the necessary chemicals. They also take in hand the analysis of any water which it may be desired to soften. As to the reliability of the analysis much depends on the respectability of the firm and the skill of the chemist employed by them.

CHAPTER II.

THE INSTALLATION OF A BLEACH WORKS.

Water Supply—Steam Boilers—Steam Distribution Pipes—Engines—Keirs—Roller Washing Machines, Stocks, Wash Wheels—Chemicking and Souring Cisterns—Various Suggestions—Buildings.

WHEN a bleach works is to be established the bleacher generally finds that he is controlled in his plans by existing plant, such as buildings, boilers, engines, etc. In such a case he endeavours to profit as far as possible from existing arrangements, and to place the new plant in such a manner as will incur the least expense. More or less costly adaptations are then made, but which, taking everything into account, often cost more in the end than new plant would have done. It will be supposed that a new bleach works is about to be started, and it is desired to ascertain what is the best arrangement of plant to be made. All bleaching processes are included in the five following operations: Lye-boiling, chemicking, souring, washing, and exposure on the bleaching green. These operations require water, steam, and motive power.

1. *Water Supply.*—This question, as has already been seen, is of the greatest importance, because washing plays a vital rôle in bleaching. Water must be available not in large but in sufficient quantity. A bleach works should therefore only be established in a district where it is certain that there will never be a dearth of water. The quality of the water must also be taken into account. It should be bright, colourless, and not too calcareous. Certain sulphated ferruginous and

ochry waters are altogether unfit for bleaching. The water is drawn from wells, cisterns, or streams, and the particular circumstance of each case will decide the kind of pump to be used. Centrifugal pumps have a good output when they work by return flow, and a bad output when the aspiration depth exceeds 5 feet. The water should be stored in as large a reservoir as possible, and on such an elevated situation as will enable it to be delivered at a suitable pressure into all the machines. The bottom of the reservoir should be 12 to 13 feet above ground level. The water is distributed into the different departments by mains and by smaller pipes to the different machines. Valves at convenient spots serve to isolate the branch pipes for repairs, or in winter nights when the pipes should be emptied for fear of frost. A main drain in the centre of the factory carries off the wash waters, spent saline lyes, chemicks, and sour. This drain is ventilated and large enough to be entered and cleaned. The exit is at a high enough level for the water to run into the discharge canal, and not reascend into the drain. In other words, there should be a good fall to a clear outlet. All the bottoms of keirs, chemicking, and souring cisterns should be high enough for the water to flow to the main drain. All the main drains should be placed beneath the passages so that they may be easily inspected and cleaned.

2. *Steam Boilers.*—High-pressure steam boilers, 8 to 12 atmospheres, answer very well for steam engines with a regular consumption. But to meet the requirements of a bleach works it is better to choose low-pressure boilers, 4 to 5 atmospheres, containing a large quantity of water and a great reserve of steam. When a lye is being heated there is at first a great consumption of steam to bring it to the boil, after which it requires but a small quantity of steam to keep it boiling. Steam is thus taken from the boiler in an irregular manner. If the boiler has not got a great reserve of heating power the pressure will soon fall and the stoker will have to urge his fires so as to get the steam up to the right pressure. He cannot therefore stoke his fires regularly, and will consequently

consume much more coal. If the bleach works be on a large enough scale to warrant it, it would be advisable to provide steam boilers for the engines and for those machines which are driven by their own motor, and separate ones for heating the lyes, etc. In many bleach works it is the practice to make the lyes during the night. It saves time, seeing that in the morning the fabrics are ready to be taken out of the keirs to undergo other treatment. Working in this way a greater amount of work can be done with a smaller number of steam boilers. During the daytime they provide steam for the engine and at night for heating the lyes. Space should be left for laying down boilers alongside those previously existing. The spot reserved for them may be used to store coal or other materials. It is very annoying to have boilers scattered all over the works. It should be easy to get at the boilers. One should be able to get them out for repairs without breaking down great lengths of wall or having to resort to measures of extreme difficulty. The coal store should be near the fires. The arrangement of flues which lead the smoke to the chimney should be carefully studied. By neglecting this precaution incredibly absurd directions are given to the flues, resulting in a bad draught and annoyance of every description which might easily have been avoided by more serious consideration at the time they were built. Drying chambers are sometimes built above the boilers to utilize the heat. The author does not advise this being done. White fabrics cannot be dried therein on account of the coal dust. As to building drying chambers for substances uninjured by dust, by separating them from the top of the boilers by perforated boards, such a structure might lead to a fire on account of the cotton waste, etc., and, in any case, does not lead to cleanliness, an object already difficult enough to attain. It is evident that the boilers should be near to the engines and the keirs.

3. *Steam Distribution Pipes.*—Copper steam pipes suit best, but they are too costly. Iron pipes are still used. There is danger of the steam carrying rust along with it. The firm of Sergot, of Paris, makes iron pipes galvanized

inside to prevent rust. It is not advisable to use cast-iron pipes for steam. Cast iron is brittle, and if a pipe burst the pieces fly about. Wrought iron or copper pipes are simply wrenched asunder. Two or three main steam pipes should be laid on furnished with unions from which smaller pipes are led to the different machines. Steam valves are fixed at the commencement of the principal pipes. The steam can thus be shut off in all the pipes when the work is finished, or when a joint starts leaking. The steam pipes should, especially the larger ones, be covered with a non-conducting composition. Simple coils of straw or reeds produce a very good effect. At different intervals syphons with taps are placed for running away the condensed water, and the slope of the pipes should be towards these taps. The new flexible pipes are useful.

4. *Engines.*—The steam engine should be placed in a central position, and the transmitting shafts should radiate from it in different directions. The machines requiring the greatest amount of force, such as the stocks and the wash wheels, are placed near the engine, but many machines in modern bleach works now work direct from their own motor (Fig. 11). If the circulation of the lye in the keirs be effected by a centrifugal pump, it is advisable to have a small special motor to drive it, so that the circulation of the lye is not interrupted during the stoppage of the engine. When lye-boiling is done in the night-time a small motor becomes necessary, because the principal engine and all the transmission shafting cannot be kept going to drive two or three pumps. It is advantageous to have transmission shafts which revolve very quickly, and to reduce the speed by gearing and pulleys so as to impart a suitable speed to each machine. This permits of installing light shafting, etc.

5. *Keirs.*—The lye-boiling keirs should be located near the steam boilers. They should be placed in line; behind them should be the cisterns for preparing and revivifying the lye. There should be two classes of keirs, one for lye-boiling at a high temperature, the other for dilute lyes, which are generally boiled at the atmospheric pressure.

6. *Roller Washing Machines, Stocks, Wash Wheels*.—A wide passage should be left between the keirs and the washing machines. The first row of washing machines should be placed in front of the keirs. These washing machines will draw the fabrics from the keirs without any necessity for intervening manipulation. Another row of washing machines should be placed between the chemicking cisterns and the souring cisterns. The fabrics which have been chemicked are drawn from the chemicking cisterns by the roller washing machines, washed and delivered through a reel into the souring cistern. In front and behind each washing machine sufficient space is left for the passing of trucks, and for the laying down of movable wooden boards, on which the fabrics, which are not to be immediately chemicked or soured, are piled. It is advisable to place small squeezers alongside the washing machines to free the fabrics from water. In those cases where only a single row of roller washing machines is to be laid down, they should be located between the chemicking cisterns and the souring cisterns. The fabrics coming from the keirs can be washed by passing them over and above the chemicking cisterns, supporting them through the intervening space by reels. The stocks, wash wheels, squeezers, and centrifugal machines may be placed further away from the keirs, chemicking and souring cisterns, as the fabrics do not pass directly from the one to the other. As these machines require a deal of motor power they are placed near to the steam engine.

7. *Chemicking and Souring Cisterns*.—The chemicking cisterns are constructed preferably of mason work and lined with cement. They are placed in a row and are in communication with a pump so that the lye may be passed from the one cistern to the other. A certain number of the cisterns are surmounted by rollers for reeling the fabrics—that is to cause them to pass from one side of the cistern to the other. Near by are placed the cisterns and plant for dissolving the chloride of lime. This workshop should be separated at least by a partition from the rest of the bleach works, on account

of the dust from the chloride of lime, which is very injurious to the health of the workmen, and which, falling on the fabrics, would lead to serious damage.

8. *Souring Tanks*.—The souring tanks are made of wood: they are placed in a row and communicate with a pump, or better still with a Koerting injector, so that the acid may be run from one basin into another.

9. *Various Suggestions*.—The best sites in the author's opinion for the principal plant used in bleaching have now been indicated. Room must, however, be reserved for the soap scouring and rubbing machines, stretching machines, etc. Different places will be chosen for storing the fabrics. The place where the fabrics are assorted and the progress of the bleaching process ascertained ought to be lighted from the north or the east.

CHAPTER III.

DEFINITION OF BLEACHING.

Object of Bleaching—Definition—Summary of Methods adopted and their Mode of Action—The Principal Points to which the Bleacher should give Attention.

Definition of Bleaching.—The object of bleaching yarn or fabrics, elaborated from fibres of a vegetable origin, is to change the colour of the raw material used in their manufacture from its original tint to a more or less pure white, in one word, to bleach it as well as to eliminate any accessory impurities by which they may become contaminated, and more or less soiled, during such operations as spinning and weaving. Flax, hemp, and cotton are the raw vegetable materials most generally used, also jute and ramie for coarser fabrics. The fibres of all these textile plants have a more or less deep yellow or dark colour. They must, therefore, be brought to the greatest possible degree of whiteness. To establish a rational theory of bleaching, it is necessary to have a complete knowledge not only of the physical structure of the fibres of each of these different plants, but also of their proximate chemical composition. We must also know what the substances are which coexist along with the essential ingredient of these fibres, and which can be removed, or converted into substances more capable of removal, in the sequence of the bleaching operations, and that too without injuring the soundness of the fibres themselves, and what the chemical products are, which, when suitably applied, bring about these modifications, without attacking those parts of the fibres, which as just said, it is desired to preserve intact. The examination of these questions is very intricate and delicate, and little progress has yet been made,

but there is no question that, in this domain, further well-directed practical research, in the true sense of the word, will yet lead to great and greater progress in the bleaching industry. Hitherto experience, observation, and rational deduction have demonstrated the rules to be obeyed, or have indicated the series of treatments which fabrics should undergo in order to bleach them. These are :—

1. *Lye Boiling*.—The alkalies, lime, soda, and potash, are used to dissolve the resinous and gummy substances; the soluble products so obtained are expelled by washing.

2. *Grass Bleaching*.—During the time the fabrics are exposed on the bleaching green air and light act on the tissues by oxidizing the colouring matters and transform them into colourless substances. This oxidation also converts the colouring matters into colourless substances more easily dissolved by lyes or more easily attackable by the “chemicks” which follow exposure on the grass.

3. *Chlorine, Chemicks*.—Chlorine, whether employed in the state of a gas dissolved in water or in the state of hypochlorite, is another energetic oxidizer. Its use as hypochlorite dissolved in water is very general and convenient. But, speaking generally, substances which evolve oxygen on decomposition are decolorizers.

4. *Sours*.—Acids are used either to increase the energy of the decolorizing principle, or to dissolve the salts encrusted in the tissues of the fabrics, or again to render soluble the compounds resulting from previous reactions and thus enable them to be eliminated by washing.

Each of these different operations has an action peculiar to itself, and they should succeed each other in a certain order. They cannot produce their effect simultaneously, but they act in such a slow, gradual manner as not to attack the constituent parts of the fibre. In fact, the fibres have first of all been twisted together in the spinning mill to make yarn, then this yarn has been woven to make cloth. It becomes therefore very difficult for chemical agents to reach the central fibres without producing an injurious effect.

Washing.—Their action is at first superficial, and the first formed products are dissolved and removed by washing. The fabric is then submitted a second time to the action of the same agents; they now penetrate more deeply into the fabric, and the products formed are expelled by a second washing, and so on.

The Comparative Ease of Bleaching Cotton, Linen, Hemp, Jute, and Ramie.—The operations vary with the nature of the substances of which the fabric is composed, and whether it has been spun with fine or coarse fibres, loosely or tightly spun, loosely or tightly woven. Cotton is easily bleached in a few operations; linen bleaches much more difficultly, and requires a greater number of operations. It is also necessary to vary the treatment with the country or source of origin of the textile materials—thus, Russian linens are more difficult to bleach than French or Belgian. Hemp is bleached in the same way as linen, likewise jute and ramie; but the fabrics made of the two latter do not take a decided enough white under ordinary bleaching methods, but modern methods detailed in the sequel are more drastic and give better results.

The Art of Bleaching.—The art of the bleacher, therefore, consists in discerning and applying the operations suitable for each kind of fabric according to whatever stage it may have reached in the bleaching process. The strength of the lyes, of the “chemicks” and “sours” ought therefore to be fixed and determined. If they be too strong, the soundness of the fabric suffers and it is “tendered”; if they be too weak, the fabrics must receive supplementary treatment: hence, there is loss of time, manual labour, and chemicals, and the more the fabrics are handled, the more they risk being damaged. It is therefore necessary to work so that each operation may be carried out under the best possible conditions, and although that involves rather considerable care and attention, this method of procedure is invariably the best.

The Chemical Control and Systematic Working of a Bleach Works.—It is not at all necessary to have extensive chemical knowledge to be a good bleacher, but it is very advisable to

have some knowledge of the chemical products in most general use, so as to be able to make a valuation of them when delivered by the drysalter. The bleacher ought also to titrate the lyes, the chemicks, and sours so as to make them of the right strength. The bleaching industry is not very complicated, but it requires great faculties of observation and much system and order. The fabrics as they are being bleached must be often examined to ascertain the result of each operation, and as these are numerous, a register must be kept of the different treatments each lot of fabrics is receiving simultaneously. From the data afforded by this register the work of the bleaching house may be regulated and systematically controlled. The strength of the lyes and the chemicks should be tested and regulated every day by the foreman, and from time to time by the manager of the works. None of the prescriptions indicated for each operation should be neglected, because an operation badly done by damaging a large number of fabrics is the cause of considerable loss.

CHAPTER IV.

STEEPING.

Reason for Steeping—Temperature of the Water—Duration of the Process—Different Methods—When Steeping may be Dispensed with—Steeping in Spent Lye.

THE first operation in bleaching where the goods are not intended for calico printing, or are to be dyed in plain colours and do not therefore require singeing, is drenching or steeping. Indeed, some authorities, e.g. Ure, recommend steeping prior to singeing, as the latter operation baked the impurities on to the cloth and so rendered them insoluble in water and indifferent to ordinary bleaching agents. The end in view in steeping is to get rid of the surface coating of grease, oil, dust, and dirt, and of various substances with which the yarn gets impregnated before and during weaving. The fabrics are allowed to steep in water heated to 60° C. (140° F.) for about eighteen to twenty-four hours. The water must be hot enough to start the fermentation of the surface coating, render it soluble, and thus enable it to be eliminated in the washing; but on the other hand, it must not be heated too highly, because it would then bake the surface coating, which would be more difficult to eliminate afterwards. Fabrics should not be allowed to steep too long, because prolonged fermentation would entirely destroy them. When the water commences to give off a bad smell it must be run off and renewed, if the fabrics are not to be washed immediately. One plan is to have a reservoir in which the water is heated beside the keir. The hot water is run in from the reservoir at the same time as the keir is being charged with the fabrics. This water is at first heated to between 70° and 80° C. (158° to 176° F.), but

it quickly descends to between 50° and 60° C. (122° to 140° F.). It is not necessary to have a large reservoir to heat the water. A small reservoir is fixed at a higher level than the steeping keir. Water and steam are led to the bottom of the reservoir. The flow of water and the quantity of steam are so regulated as to produce the temperature required, and the hot water is run in, in requisite proportion, on the fabrics as they are being laid in the keir.

A second plan is to run in a current of cold water as the fabrics are being placed in the keir, and then to heat the steeping-keir and its contents by a steam pipe placed below its false bottom. The disadvantage is that the fabrics near the steam are overheated, and the others not sufficiently so. A third plan consists in filling the keir with cold water and heating the water to 75° C. (167° F.). The fabrics are then pressed into the liquid with a stout stick. The fabrics occupy a much larger space and a much smaller quantity can be placed in the keir. Two hundred to 300 kilogrammes of fabrics can be put into a cubic metre (or say 200-300 lb. in the space occupied by 100 gallons of water). The keirs used for boiling with alkaline lye may be used for steeping. If special keirs be allocated for this purpose they may be made of mason work, with an internal coating of cement. They last indefinitely, but the lining of cement is eventually attacked on the surface. It becomes rough and uneven. In the case of fine textiles it is preferable to line the inside of the keirs with wood. Wooden keirs are very convenient: they can be shifted from one position to another. To economize time and working expenses, steeping is dispensed with and the textiles are at once treated with lye. Doing away with the steeping is not to be recommended, because soda at a high temperature does not dissolve the surface coating of the fibres very well, and it hinders the action of the lye. Steeping may be dispensed with when a lime-boil is given, because lime energetically attacks the surface coating. In certain bleach works this method has been in use for many years both for linen and cotton fabrics without any mishap. But with fabrics woven

with cream-coloured yarn, it is prudent to commence operations by steeping. As a matter of fact, cream-coloured yarn has not been very well washed after the chemick. Steeping, followed by washing, removes any remaining chlorine, and renders the performance of the subsequent operations safer. Steeping ought always to be followed by washing. Several bleachers, to get better results from the steeping, add a little soda crystals to the water, say 1 lb. of crystals to 100 lb. of textiles. Spent lye, which is kept in reserve for steeping, is also used. The results obtained are not appreciably superior to those obtained with hot water.

CHAPTER V.

SINGEING.

Singeing.—During calico printing, if the nap or loose projecting fibres on the surface of the cloth had not been previously removed from the surface of the fabric by ignition, the impressions made by the printing machinery would be faulty. The principle of the process or the object aimed at is to remove the superfluous nap or loose fibres without injuring the texture of the cloth itself. This is effected by quickly passing the fabric in the open width over red-hot plates, red-hot cylinders, or over one or more rows of bunsen burners. The machine for singeing by coal gas generally consists of one or more rows of bunsen burners above which the cloth passes so that a full line of burners stretches along the whole width of the piece. The distance of the cloth from the flame can be readily adjusted by means of levers, or the jets may be withdrawn altogether.

Gas Singeing Machine—Horizontal Type.—The burners on this new model of singeing machine are arranged on a horizontal plane, and are thus more easy of access for the passage of the fabric than with the old type of machines. The burners are on the Descat Leleux type; the width of the flame is adjusted by a screw regulator. The rolls over which the fabric pass allow the fabric to be singed at will on one or both faces. The flame attacks the fabric between the rolls which enables it to spread out better and to sink into the fabric so as to bring out the texture. In front are placed three drying rolls heated by steam to dry the fabric thoroughly so that the singeing is more rapid and economical; the first burner does the singeing forthwith instead of merely serving to dry the fabric, as too often happens. A system of rotary brushes raises the pile

of the fabric on the spot and in an inverse direction. A steam box behind extinguishes the inflamed meshes. The burners are fed by a blower under pressure. The machine is started by a gradually increasing motion.

Patent Gas Singeing Machine.—This singeing machine is claimed to possess many important advantages. Great economy of gas is effected by ensuring that the flame is brought into contact only with the fabric to be singed, so as

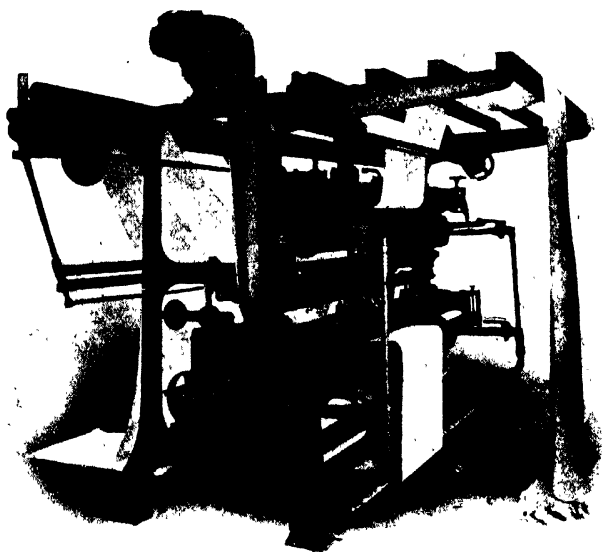
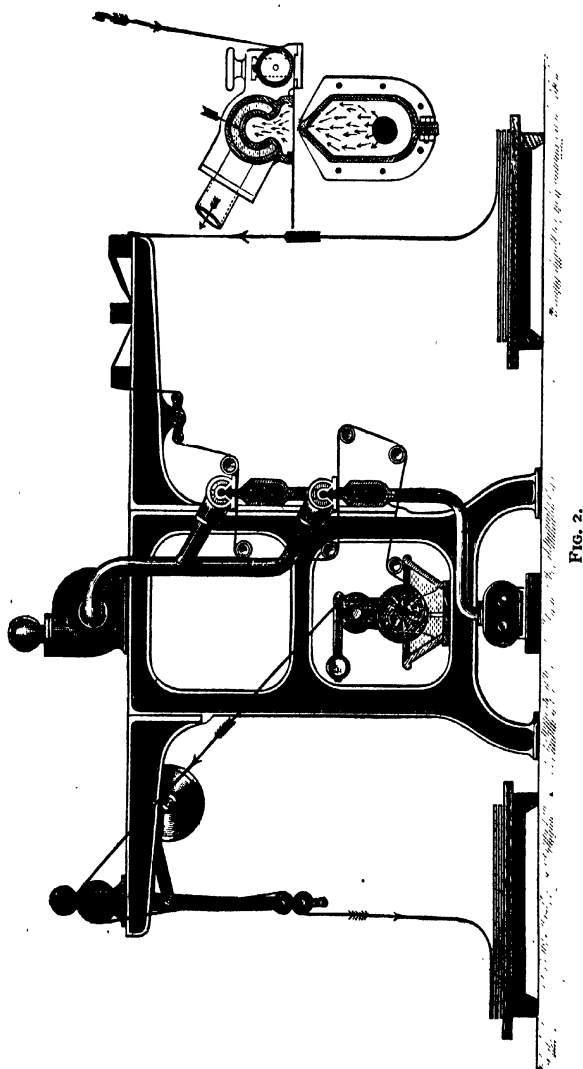


FIG. 1.—Gas singeing machine.

to be most effective, instead of being wasted to a large extent, as in previous machines, in heating the metal guide rollers against which the cloth was singed. The cloth while being singed passes across a slot in the underside of an exhaust chamber connected to a fan, and the flame from the burner below is drawn gently through the cloth by the current of air. A very important feature of the machine is the prevention of overheating of the exhaust chamber by surrounding it with a water-jacket through which a current of cold water flows.



Owing to the efficient manner in which the flame is utilized one burner is ample to singe perfectly on one side the finest

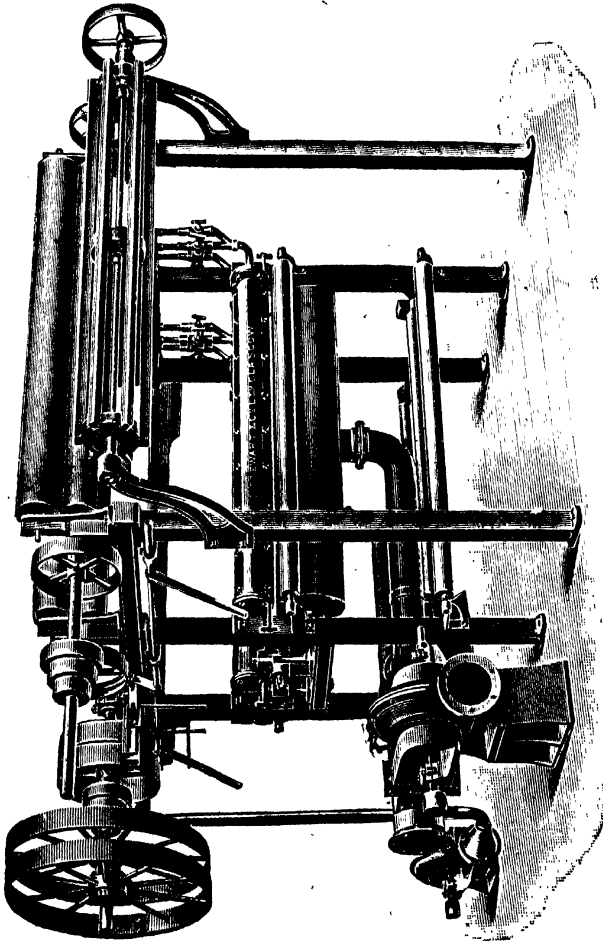


FIG. 3.—Horizontal gas singeing machine (Duncan Stewart & Co., Glasgow).

quality of cotton goods for printing, and by adding a second burner the machine can be arranged to singe perfectly both

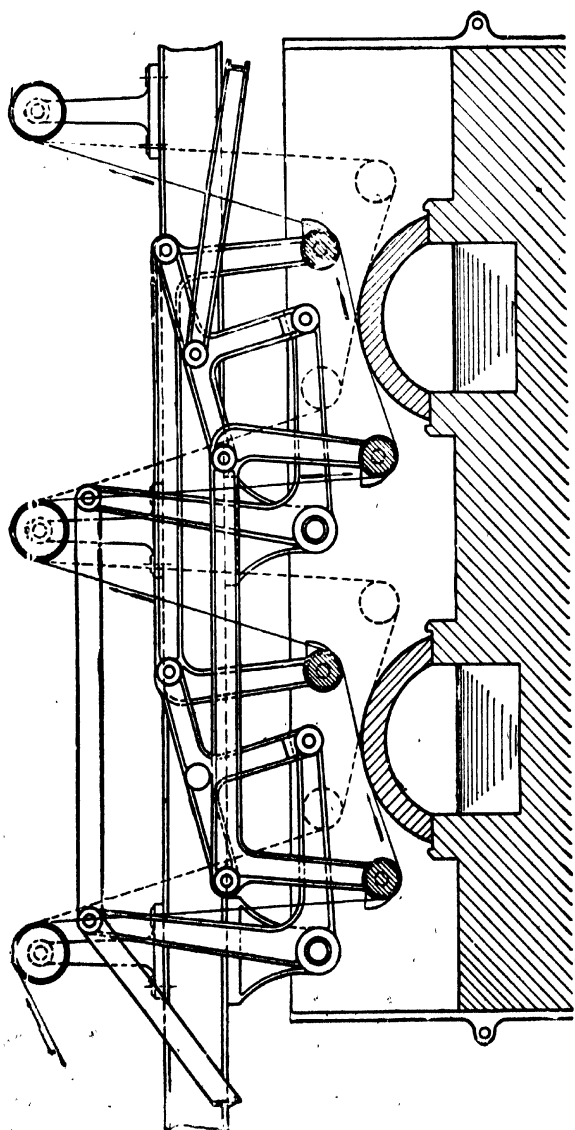


FIG. 4.—Hot-plate singeing machine, with mechanical arrangement to prevent too long contact and scorching of fabrics.

sides of the cloth. From actual experience it has been found that on applying this improvement to one of the burners of an existing two-light gas singeing machine it became unnecessary to use the second burner ; the production of the machine was more than doubled, the quantity of gas consumed was reduced from 260 to 160 feet per hour, and the quality of the work done under these conditions was superior to that previously obtained. On account of the high speed practicable with this improved machine, the small quantity of gas employed, and the manner in which the machine is controlled, the cloth singed by it is not impoverished to the touch, nor is it weakened, as proved by many comparative trials of strength on the cloth-testing machine, whilst the nap is most thoroughly and completely removed from the surface.

Hot-Plate Singeing—Improved Method.—The great drawback to plate singeing is difficulty experienced in keeping the plates at a regular bright red heat as the plates are rapidly cooled by the pieces in their passage. The revolving singeing roller was designed to remedy this defect. The flames of the furnace pass through the interior of a revolving hollow copper roll or cylinder so that a nascent red hot surface continuously acts on the piece, singeing it evenly and uniformly. This hot plate or cylinder singeing is preferably used for heavy massive cloth, but for light thin delicate fabrics, such, for instance, as muslin goods, singeing by gas has proved to be best. Too long prolonged contact with the hot plate is also avoided by elaborate mechanical arrangements, such as those shown in Fig. 4.

CHAPTER VI.

WASHING: ITS END AND IMPORTANCE.

ROLLER WASHING MACHINE.—*Description—Tension and Non-Tension Washing Machines—Speed—Dimensions of the Rolls—Distribution of the Water—Number of Spirals—Entrance and Exit of the Pieces—Duplex Roller Machine—Damage done by the Roller Washing Machine.*

WASH WHEEL (DASH WHEEL).—*Description—Practical Information—Damage, Precautions to take—Advantages and Disadvantages of this Method of Washing.*

STOCKS OR WASH MILL.—*Description and Hints—Management of Wash Mills—Advantages and Disadvantages of this Method of Washing.*

SQUEEZING.—*Its Utility—Draining—Centrifugal Hydro Extractor—Roller Squeezing Press.*

Washing: Its End and Importance.—The different bleaching operations, such as lye-boiling, chemicking, souring, ought always to be followed by washing. Too much special care cannot be taken in washing, for on it depends all the safety of the processes used. When the fabrics are damaged or tendered, it is more likely to be due to insufficient washing than to too strong lye-boils, chemicks, or sours. Lye-boiling renders the resinous or gummy matter of the fabrics soluble; but a portion only of these substances is carried away by the lye-boil: the other portion, the elimination of which is the object of washing, remains in the interior of the fabric. Washing also removes the lye with which the fabrics are impregnated after each lye-boil, an important point, especially if the fabrics are afterwards to be exposed on the bleach-

ing green. The action of air on soda lye, especially on caustic soda lye, in contact with the fibres, has the effect of damaging the fabrics very quickly. The fabrics must be washed as they come out of the chemicks and the sours, because both the chemicks and the sours continue to act upon them and rapidly damage them. Washing ought to follow the chemick and the sour very closely, and it is especially necessary to prevent the fabrics from drying in the interval. Carbonate of soda in solution crystallizes with 10 molecules of water and the force of crystallization may rupture the fabrics. The main object of washing is to prevent the different chemicals used in bleaching from coming in contact and reacting too violently—the one on the other—and that too in immediate contact with the fabrics. For example—after a lime-boil the fabrics are soured, and that sour is intended to remove the lime which has penetrated into the interior of the fibres of the fabric. It is, first of all, necessary to wash the fabrics, as thoroughly as possible, between the lime-boil and the sour. If this were not done, the acid, coming in contact with a greater or less quantity of lime, would react on it violently, and the conversion of a considerable quantity of lime into calcium chloride does not take place without injuring the fabrics. Washing—between the chemick and the sour—is also necessary. If the fabrics be still impregnated with chemick when they are soured, the acid liberates chlorine very briskly, which reacts on the fabrics, with the risk of damaging them. This method is sometimes adopted to increase the energy of the chemick, but it must be used with great caution.

1. *Washing by the Roller Washing Machine*¹—*Description*.—This machine consists of two hardwood rolls, the one turning on the other. The lower roll is driven by a belt or gearing, and the upper roll turns round in the train of the lower one. Below these rolls there is a trough of wood or cement, filled with water, which is constantly being renewed. The fabric, drawn by the rolls, descends into the trough to be

¹ See illustration (section, elevation, and plan) of roller washing machine on pages 127-128, 129 (Figs. 23, 24, 25, 26), as it is used for saturating fabrics with alkaline lye.

washed, passes below a cross piece or a roll fixed near the bottom, rises on the other side to pass a second time between the rolls and re-descends again into the trough, and so on a dozen of times. The lengths circulate spirally. The machines are provided with various cross pieces to regulate their proper working and ensure thorough washing. (See Figs. 5 and 6.)

Roller Washing Machine (Non-Tension).—This type of washing machine has been specially studied with the view of

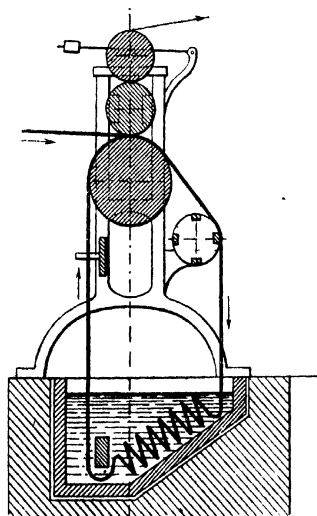


FIG. 5.—Non-tension roller washing machine.

increasing its output. It consists of two wooden rolls surmounted by two pairs of small cast-iron rolls covered with india-rubber forming a stretcher at the entrance and a squeezer at the exit (Fig. 6); an octagonal turner to lower the pieces; a rake guide with to and fro motion; automatic clutch, stopping the machine if a knot is found in the piece; water injector; tank for the evacuation of dirty water coming from the squeezer, driven by friction pulley; wooden case with partitions and venetian blind shutters.

The upper roll is surmounted by two small rolls (Fig. 6) placed at its extremities. The object of the first is to stretch out the cloth as it enters, and that of the other is to squeeze it as it comes out of the machine. The pressure on the rolls may be increased by weights fixed to the end of levers, which press on their axis. On the side where the fabrics descend, a reel, revolving at a greater speed than the rolls, draws in the

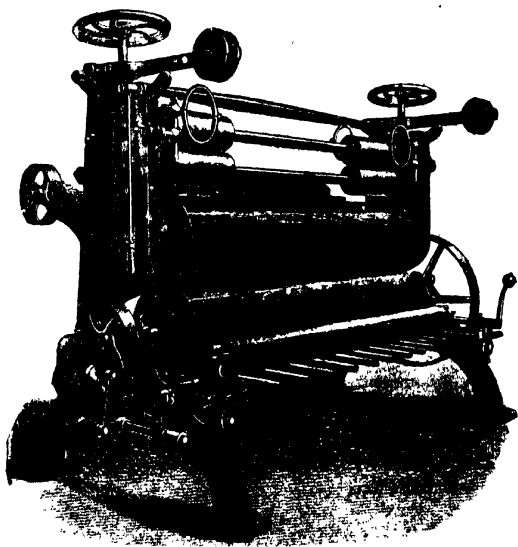


FIG. 6.—Roller washing machine (non-tension) (F. Dehaitre).

lengths, and hinders them from sticking to the rolls and from getting rolled round them, which is a frequent cause of damage. In the bottom of the cistern is a cross piece, underneath which the fabrics pass, and are thus forced to sink into the water. Sometimes the different pieces are separated by partitions, which hinder them from being entangled in the washing cistern. On the ascending side, the strands are guided by a hexagonal cylinder, which causes them to circulate spirally. A pipe brings the water to the cloth exit side. The

discharge pipe is on the cloth entrance side. The washing is therefore methodical. It is unnecessary to enter into the details of the construction of these very simple machines. The reason which has led to different modifications will alone be given.

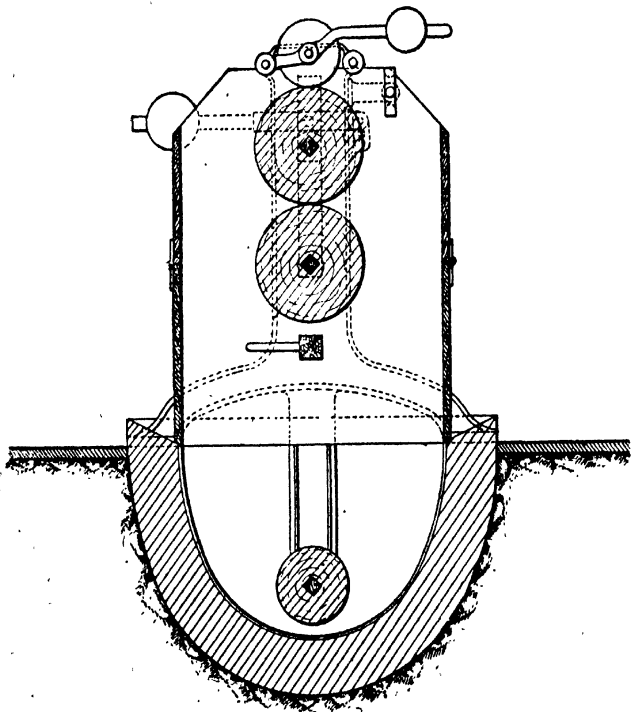


FIG. 7.—Tension roller washing machine (F. Debaitre).

Tension Roller Washing Machine.—In the tension roller washing machine (Fig. 7) all the pieces are stretched. In the bottom of the washbeck is a roll which turns on its own axis by the movement imparted to it by the fabric. This plan is adopted in roller washing machines of high velocity (the pieces revolving at the rate of 10,000 metres ($6\frac{1}{2}$ miles) an hour), in

which case there would be danger of entanglements if the pieces were not stretched. This arrangement is also used in the case of coarse sheetings, which are very stiff, and which would not sink into the water if they were not stretched. In the non-tension roller washing machine 10 to 13 feet of cloth are left slack, which dip in the water and work about therein. The water, in this way, penetrates better throughout the fabric. To use this system, the fabrics must not be too stiff or too bulky, and the speed should not exceed more than 3 to 4 miles an hour.

Speed—Size of Rolls.—The speed depends on the nature of the pieces to be washed. In certain tension machines a speed is given to the pieces of 5 to 6 miles an hour. To work at this speed the fabrics require to be light and spongy. The workmen who look after the roller washing machine ought to be very careful, for the slightest tear is the cause of considerable damage. When very large pieces are being treated, the speed of the pieces is reduced to between 1 and $1\frac{1}{2}$ mile per hour. In the non-tension machines a good speed to adopt, in the washing of light fabrics, is 3 to 4 miles per hour. This speed is reduced when washing heavier fabrics. The lower driving roll ought to be big enough to present a large contact surface to the fabrics, and to draw them in without slipping. A diameter of 2 feet is a very suitable one. When the roll is worn it is turned over, but when the diameter gets less than 18 to 20 inches the roll is of no further use, or it must be refitted with wooden staves to bring it to its primitive diameter. The rolls are sometimes encircled with hemp or aloes rope. It is the rope which wears; the diameter of the roll remains constant. The upper roll serves to press the pieces on the lower roll so as to facilitate their being drawn in; its diameter is less than that of the lower roll, varying from 12 to 16 inches. At the two ends of the roller washing machine, and fixed to the building, is a system of screws or levers by which the upper roll may be rapidly raised so as to withdraw the goods, in case of accident, or to regulate the portions floating unstretched in the cistern. When the pieces pass always

over the same part of the rolls they eventually run into grooves, and the drawing-in power, due to the pressure of the upper roller, is diminished. It is advantageous to vary from time to time the position of the ladder which determines the direction of the spirals, so as to use up the rolls in a uniform manner. The wood which suits best for rolls is beech or plane tree. It is necessary to use wood which has been felled a long time previously, and which has been preserved under water.

Distribution of Water—Quantity to Furnish.—It is rational for the water inlet pipe to be on the side of the trough where the fabrics come out, and for the exit pipe to be on the side where they enter. To ensure perfect washing it is necessary that the water in which the pieces dip, for the last time, before their final exit should be almost pure. By examining the water, on the exit side, a few times, its state of purity is ascertained, and the outlet and inflow of water regulated accordingly. Generally, 150 to 220 gallons of water are used up per minute. In certain machines the water is not simply run into the troughs: a horizontal perforated pipe distributes the water, in a shower, on the fabrics; at the same time, a drum, studded with wooden rods, gives them a to and fro motion which facilitates the penetration of the water. This system yields very good results. To see whether the pieces are well washed, a little of the water with which they are impregnated as they come from the wash is squeezed out and tested with litmus paper as to whether it is acid or alkaline. If either, it is necessary to increase the water or to resort to fresh washing.

Number of Spirals.—This number should not be less than eight or ten to secure good washing, and requires rollers of 10 to 12 feet long. If, working in this way, the washing is still imperfect, the pieces are passed through the roller washing machine a second time, or a double roller-washing machine is used.

Entrance and Exit of the Pieces.—The entrance of the pieces is guided by a porcelain "pot eye". Sometimes,

alongside the entrance, the rolls are surmounted by a small compressing roll, which renders the traction more energetic. The fabrics are brought, in waggons, to the front of the washing machine, or they may very well be wound directly from the lye-boiling keirs, chemicking or souring cisterns. When these machines are at a long distance from the washing machine the pieces are supported and guided by wooden rolls, turning freely round their axis to diminish friction. These rolls are vertical or horizontal according to the direction to be given to the pieces. At the exit side it is very convenient to have a compressing roll to squeeze the pieces. A workman collects the pieces and makes them into bundles, or piles them in folds in the waggons. Mather and Platt of Manchester make a folder which piles the pieces mechanically on the waggons. The fabrics may also be piled directly into the lye-boiling keir, the chemicking or souring cisterns, by means of a traction roll which delivers them into the receivers. This roll should be simple and draw the fabrics by adherence, and not by the friction of two rolls, the one upon the other. Owing to the difficulty of making the speed of the washing machines and the rolls agree, there would inevitably be jerks injurious to the fabrics.

Stitching.—The pieces are joined together, the one after the other, by laces sewn to their ends, or by pieces of twine attached to their corners. Sometimes fine pieces are tied together by their ends. The knot must be tied with great care, and it must not be too big, because there would be a risk of its cutting the fabric as it passed through the rolls.

Duplex Roller Washing Machine.—This washing machine is formed by two machines coupled together, in which the lower rolls are connected by gearing. These two rolls make exactly the same number of turns per minute, and are of equal diameter, the speed on their circumference being rigorously identical. There is therefore no risk of jerking. This arrangement has the advantage of giving a double wash without extra cost of labour or loss of time. It is, moreover, used for treating the fabrics with lye, and to wash them

immediately afterwards ; the first trough contains the lye, and the second the running water to wash the fabrics.

Damage Due to Washing Machines.—To avoid damage, it must be seen that the rolls are in good condition, that they have no asperities or knots, that foreign bodies, nails, bits of iron, etc., do not get incrustated or imbedded therein, and to guard against this they should be frequently inspected.

Damage Due to Pebbles.—A frequent cause of damage arises from the fabrics as they come from the bleaching green containing pebbles in their folds. If they are washed, in that condition, by the roller washing machine, the pebbles in passing between the rolls make holes in the fabrics. This danger is avoided by raising the upper roll. If the washing machine be working under tension, the adherence suffices to draw the pieces. In non-tension machines it is difficult to pass the pieces under the upper roll. To increase the adherence, a canting roll is used, only the ends of which are turned. The turned parts are surmounted by small rollers, the pressure of which draws the pieces, but this pressure ought to be slight, so as not to damage the fabrics if there be small pebbles in the folds. The best thing to do, however, is to take care that the bleaching greens are well kept, and that the fabrics run no risk of bringing pebbles or other hard substances in their train. When the machines exert too great a tension on the cloth, they may break the selvage, or deform the designs of the fabric. If the pieces be light and delicate it is preferable to use a non-tension machine.

2. *Washing by the Wash Wheel Description* (see Fig. 8).—This machine consists of a wooden drum-shaped cylinder, divided in the interior into four compartments, and turning on its own axis. This cruciform axis forms a passage for the water, which filling the compartment, issues from the circumference in which holes are bored for the purpose. The fabrics are introduced into the compartments ; during the time the wheel is revolving they are projected against the sides of the partition and the circumference ; the water with which they are impregnated is expelled, by the shock, time after time, and

it is this effect which produces the washing. The wheel is supported on its axis by spokes. The axis carries, behind the wheel, pulleys or gearing by which it is driven. A clutch, fixed on to the shaft, is used to stop the wheel, which would continue to turn on its axis for some time by its acquired velocity. The nave of the wheel is of wood, and is prolonged to the outside by iron arms, bound together by four bolts passing through the wooden nave. On the front face of each compartment is an elliptical aperture for introducing and taking out the fabrics. They are deposited on a wooden or stone

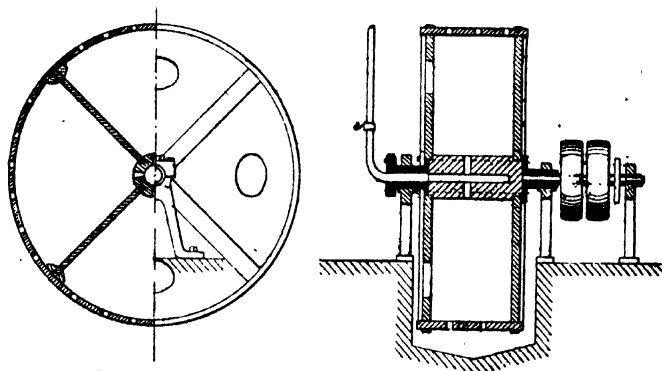


FIG. 8.—Wash wheel.

platform, built for this purpose, in front of the wash wheels. The following figures refer to a wheel having the undernoted dimensions: Diameter, 2 metres ($6\frac{1}{2}$ feet); depth, 60 centimetres (2 feet). The number of turns per minute, 20 to 22. Diameter of pipe which brings the water, 40 millimetres (1.57 inch). The flow per minute, 225 litres (say 50 gallons). The weight of the fabric put into each compartment, about 10 to 12 kilogrammes (23 to 28 lb.). The length of time of washing in the wheel varies with the operation which has gone before. The following times, fixed by experience, may serve as standards to go by for light fabrics:—

BLEACHING OF LINEN, ETC.

FABRICS COMING FROM—		DURATION OF WASHING
Steeping	- - - - -	10 minutes.
Lime-boiling	- - - - -	15 to 20 "
Sour after lime (Grey Sour)	- - - - -	15 to 20 "
Lye-boiling	- - - - -	12 "
Chemick	- - - - -	12 "
Sour after chemick (White Sour)	- - - - -	15 "
Last washing before finishing	- - - - -	20 "

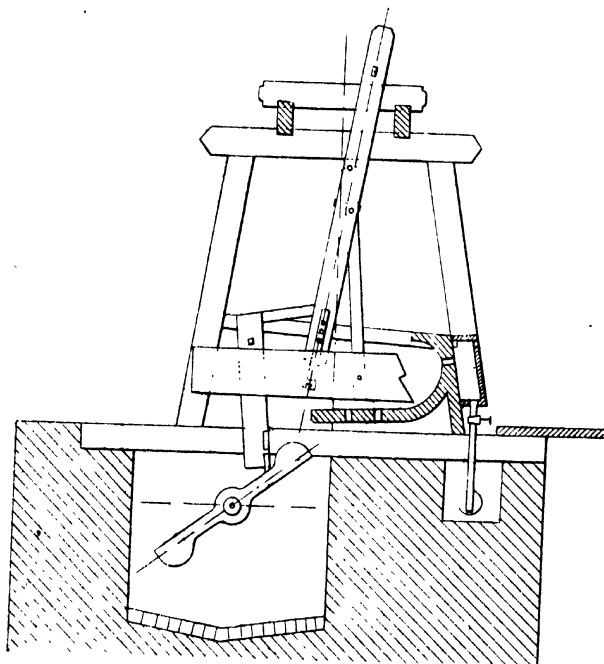


FIG. 9.—Stocks or wash mill.

Damage—Precautions to Take.—This machine causes little damage ; the fine pieces, occupying a small volume, are washed in it. The workman, in taking out the fabrics, should not pull them too roughly for fear of tearing them. When the wheel is at work there is a risk of the pieces coming out by the aperture and rolling round the shaft. The aperture there-

fore should not be too big, a length of 14 inches for the long axis and 10 inches for the small axis is very suitable. The boards should be well adjusted and tight. If during working they get dislocated, receding from and approaching each other, they pinch the fabrics and tear them. Care must be taken that no asperities are produced inside the compartments, e.g. protruding nails, cracks in the timber, etc. When the water is calcareous a very hard coating of lime is deposited on the surface of the sides and shales off; this calcareous deposit must be removed, from time to time, when it gets too thick.

Advantages and Disadvantages of this Method of Washing.

—Washing by the wash wheel is a very good method, because it does not wear the fabrics. During the process the pieces are projected against the sides, and the water which penetrates them is expressed with the dirt which they contain. If hard bodies, pebbles, pieces of wood, etc., have got entangled in the fabrics, there is less chance of damaging the latter than with the washing machines or wash mills. The disadvantage of this method of washing is that it costs much more for labour, and takes up much time. As only 10 to 12 kilogrammes (22 to 26 lb.) can be put into each compartment, it is only suitable for light fabrics, such as handkerchiefs, embroidery, ribbons, and short lengths. To wash coarse sheets, they must be divided into small sections.

3. *Washing by the Stocks or Wash Mill.*—The illustration, Fig. 9, shows the arrangement of a set of stocks or wash mill. In these a piece of wood, in the form of a hammer, is suspended from an axis, around which it oscillates. This hammer carries a handle in its lower part, and a cam, striking against it, raises it to a certain height and then lets it fall back. The fabrics to be washed are placed in a wooden drum of an oval form, into which the water runs. The water penetrates into the fabrics as the hammer or stock is raised, and is squeezed out by the concussion of its descent. The drums separated by partitions form a series of compartments, each having a width of 1·40 metre (say 4½ feet). In each of these there are two stocks

having a width of 65 centimetres (2 feet), and the cams are arranged so that each stock strikes the fabrics alternately. Whilst the hammer compresses the fabrics, it, at the same time, imparts to them a movement of rotation round themselves. During the time the hammer is again raised up the bundles of fabrics open, and are again thoroughly soaked with water. The water runs in through a pipe placed in front of the drum. Before being run in, it passes through a copper wire gauze, which stops small pebbles and other hard bodies. The illustration, on the scale of 2 centimetres per metre, or 1 to 50, shows the principal dimensions of the machine. Each compartment has a width of 1.40 metre (say $4\frac{1}{2}$ feet). Each hammer or stock has a width of 65 centimetres (say 2 feet); there are two in each compartment. They each strike thirty blows per minute (say double the number of the turns of the shaft). The quantity of water run into each compartment is 300 to 350 litres (say 65 to 90 gallons) per minute. The weight of the fabric is 70 kilogrammes (154 lb.). The length of time occupied in washing in the stocks is variable, according to the nature of the fabrics and the preceding operation.

FABRICS COMING FROM—	DURATION OF WASHING.
Steeping - - - - -	30 minutes.
Lime-boiling - - - - -	40 „
Sour after lime (Grey Sour) - - - - -	35 „
Soda lye-boil - - - - -	30 „
Chemick - - - - -	30 „
Sour after chemick (White Sour) - - - - -	35 „
Last washing before finishing - - - - -	45 „

Management and Working of Wash Mills.—The drums must not be filled too full; room must be left for the water to penetrate through and around the fabrics. Especial care must be taken that the fabrics, by turning on themselves, do not form a kind of ball, the interior of which is very hard. It is sometimes the fault of the machine, but more often it is because the machine has been filled too full with fabrics. The washing is defective, because the water does not penetrate into the interior of this mass. As soon as this is seen, the fabrics are separated by a push from a stick; if this does not do, the

stocks are stopped, and the pieces divided by hand. The stocks and the interior of the machine must be smooth. The distance between the stocks is regulated by partitions, etc., so that the pieces are not pinched; 2 to 3 centimetres (say $\frac{3}{4}$ to $1\frac{1}{8}$ inch) answers very well.

Advantages and Disadvantages in the Stocks of Washing.

—In this method the water penetrates the fabrics, and is pressed out by the compression of the stocks. It differs, therefore, from washing by the roller washing machine by the fact that, in the latter, the water glides over the surface of the fabrics. As the fabrics remain at least half an hour in the wash mills, and the stocks strike thirty blows per minute, they are compressed 900 times ($30 \text{ blows} \times 30 \text{ minutes} = 900$). The work is analogous to that of the washerwomen, who plunge their linen in water and compress it by striking it with a wooden post. If fine fabrics are being washed, such as muslins, cambrics, Irish linen, the water easily penetrates all through. This is an excellent method of washing, and it ought to be preferred to wash wheels or washing machines. It is not adapted for thick sheeting, and is difficult to handle unless the fabric be divided into small sections. This method of washing requires a great deal of motive power, labour, and time, and consequently costs dear.

4. *Washing by Hand.*—Washing by hand is resorted to in the case of very fine fabrics, which one would not dare to risk in the machines. A convenient way of working is to throw the fabrics into a basin, stretch them out to their full length, hold them by the hand at one end, then draw them back towards the operator eight or ten times with the other hand. The fabrics may also be put under a water pipe with a rose mouth-piece which rains the water over them. They are turned from time to time, so that the water may penetrate right through them.

5. *Washing in the Keir.*—When the boiling is finished, the lye is either run off or recuperated in a special tank, to be used over again. It is then advantageous to run first hot water on the fabrics, which removes better the lye and the

substances it has dissolved ; then cold water is run on them. If there be no hot water in stock, cold water is run on and heated by the steam coil in the same way as the lye, circulation is established, and the wash water run off ; the same operation is recommenced again with cold water until the wash water runs away clear. Care must be taken that the exit tap is fixed at the lowest point of the bottom of the keir, and that it is large enough to evacuate all the deposits. If not, dirt will accumulate below the false bottom, the circulation of the water will bring it on to the top of the fabrics, and it (the circulation) becomes more injurious than useful. If circulation be not performed, water is run in on to the top part of the keir and run out from the bottom. In this case it is advisable not to open the exit tap until the keir is filled with water. By proceeding otherwise there would be the risk of the water running through those portions of the fabrics where it encountered the least resistance, and leaving the other parts unwashed.

Elimination of Wash Water. 1. *By Squeezing and Wringing.—Its Utility.*—The end of the operations is to express the water which the fabrics retain after washing. Their utility depends on the fact that the water retained by the fabrics diminishes the energy of the action of the bleaching agents, preventing their intimate contact with the textile fabrics, and diluting beyond all measure the lyes, the chemicks and the sours. If no squeezing be done after washing, the strength of the lyes, the chemicks and the sours which follow must be increased, and yet the result is not so good. Squeezing before drying removes a portion of the water, which would take very long and be very costly to evaporate. (See Fig. 14, p. 67, and context.)

2. *By Drainage.*—The most simple method of expressing water is to pile up the fabrics after washing and let them drain for a longer or shorter period of time. The fabrics still retain a considerable quantity of water.

3. *By Wringing.*—Another method is to hand-wring the fabrics ; the water is well expressed. This method is imprac-

licable with long pieces or large quantities ; it can only be used for small lots or costly fabrics which cannot be risked in the machine.

4. *By Centrifugal Hydro Extractor.*—This machine, as shown in Fig. 10, consists of a cylindrical cage, the side of which consists of a perforated copper plate or of copper wire gauze. This cage is mounted on a vertical shaft which imparts to it a rotatory movement. The fabrics to be operated on are placed in the cage, the centrifugal force presses them strongly

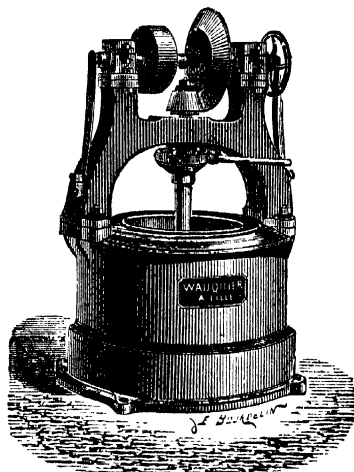


FIG. 10.—Centrifugal hydro extractor driven from above by bevel gearing.

against the side of the basket and the water is projected outside. The water is stopped by a cast-iron cover which has two orifices in its lower part for the water to run off. The rotatory movement in this type of machine is communicated to the shaft by friction cones, and suitable arrangements are adopted for the good working of the machine (clutches, lubricators, etc.). These machines are very much to be recommended because they do not wear the fabrics, and they express the water very well, provided always that they turn at great velocity. They require a great deal of force to drive and the attendant labour

is considerable. Pieces should not be voluminous, as it is difficult to get them into the cage.

The same general style of centrifugal actuated from above by bevel gearing may be driven by its own motor, as in Fig. 11.

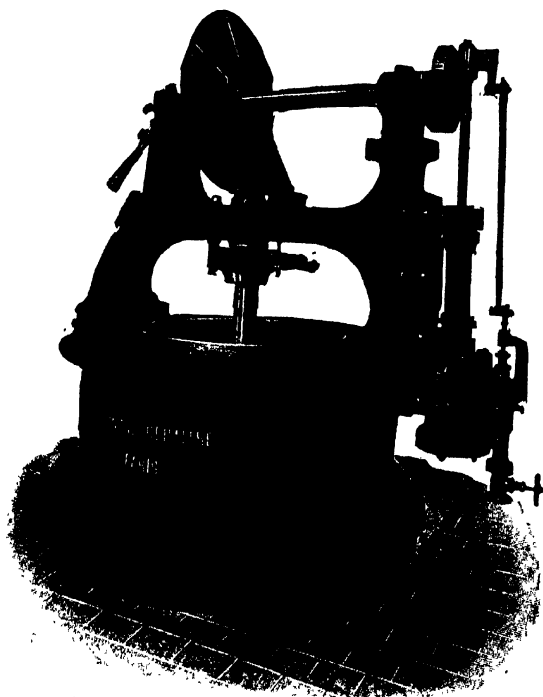


FIG. 11.—Centrifugal driven by its own motor.

Centrifugals for extracting water from washed fabrics may also be driven by electrical power, as in Fig. 12.

The illustrations of centrifugals given up to now are all driven from above. But under-driven centrifugals are less cumbersome. Fig. 13 shows a capacious massive centrifugal driven from underneath by its own motor.

Squeezing Rollers.—When the fabrics are in rolls or coils it is more convenient, and above all more economical, to pass

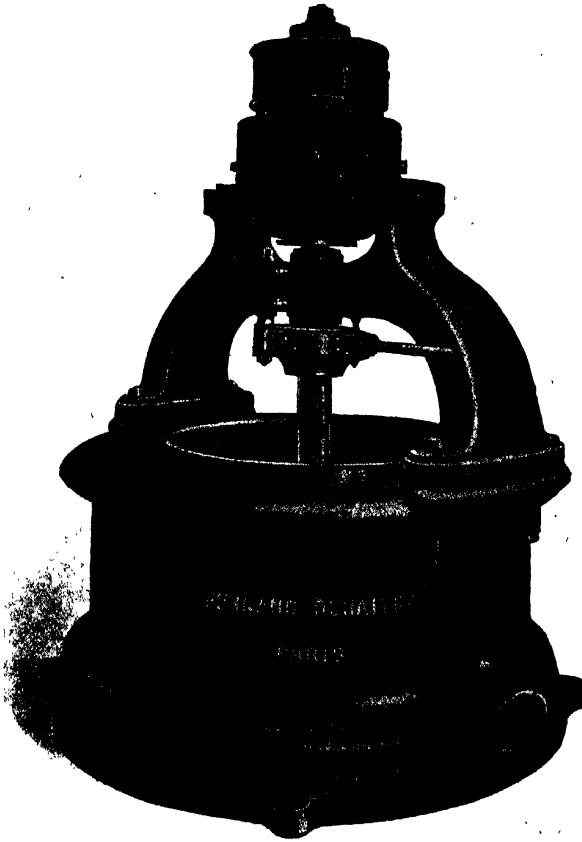


FIG. 12.—Electrically driven centrifugal.¹

them through squeezing rollers. The lower roller is driven by a belt and pulley, and the upper roller is weighted so as to act as a compressor. A "pot eye" guides the entrance of the pieces; it is given a to-and-fro motion, so that the pieces do

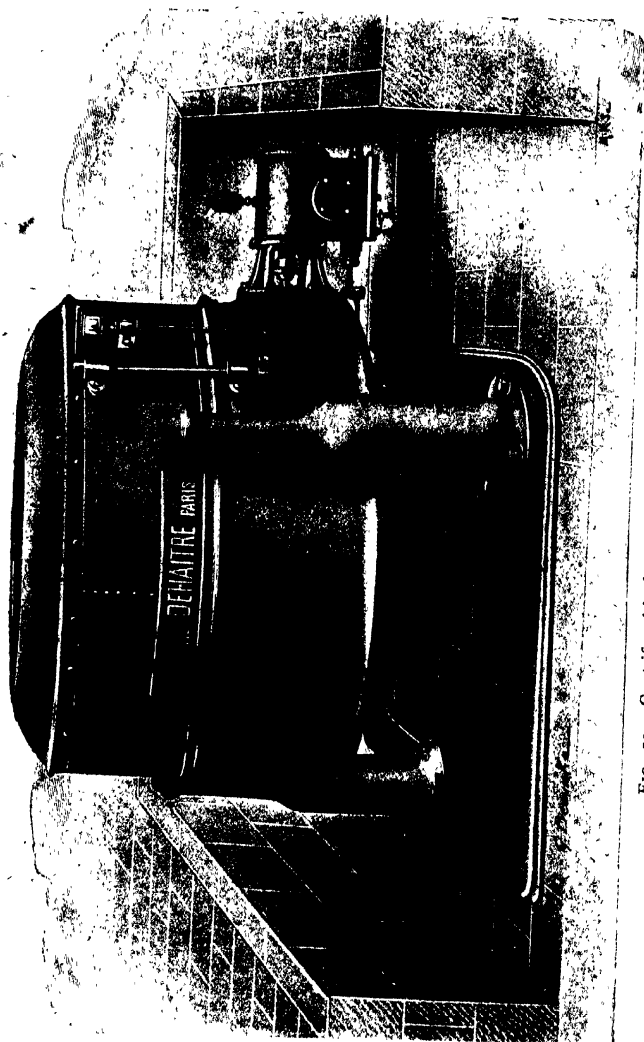


FIG. 13.—Centrifugal hydro extractor driven by its own motor

not always pass over the same place, which would form a groove in the rollers. Sometimes the rollers are covered with hemp or aloes rope; the rope is then worn and not the rollers, and the pressure is stronger.

It is advantageous to place this machine next to the roller

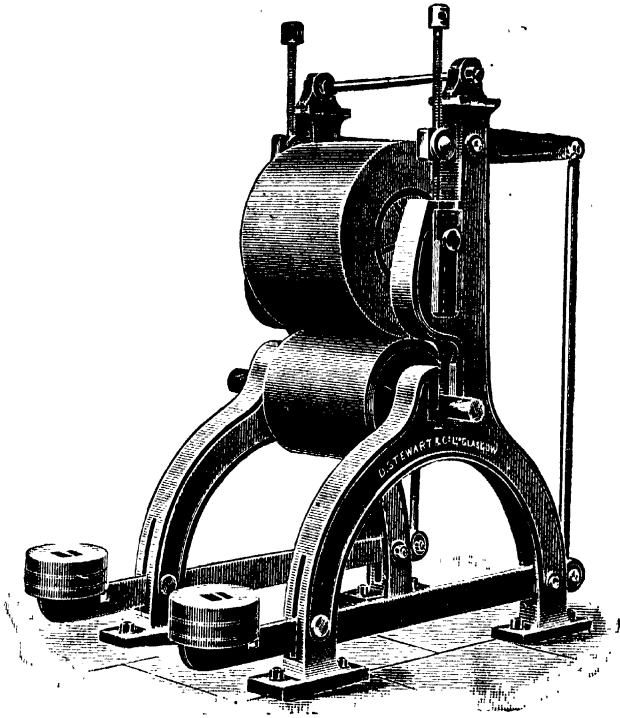


FIG. 14.

washing machines. The pieces pass directly from the washing machine to the squeezer, and there is economy in labour.

Water Mangle or Squeezer with 3, 4, 5, 6, or 7 Rolls for Expression (of Water) at Full Width or for Finishing.—The water mangle or water calender is a most useful machine for

treating cotton or linen fabrics. The three-roll water mangle or squeezer, as shown in Fig. 15, is successfully used to express (at full width) the water remaining in the fabric after bleaching and before dyeing operations, to purify the fabric, to pre-

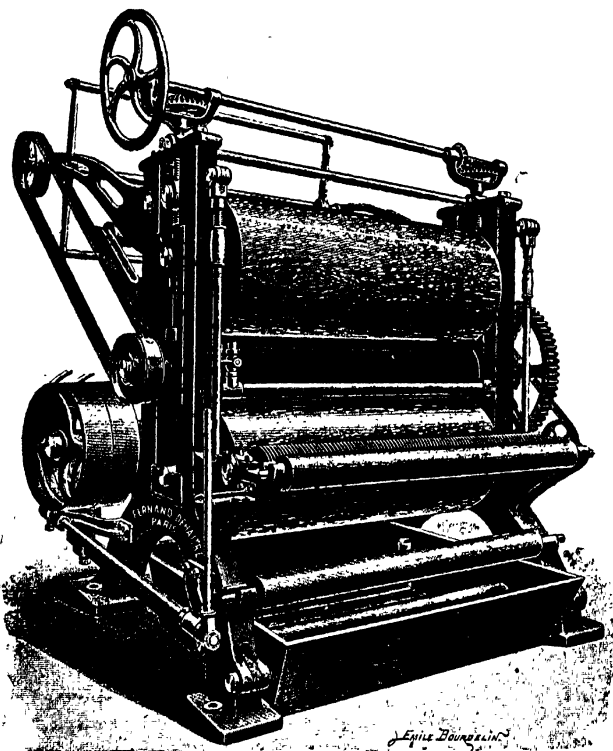


FIG. 15.—Water mangle (Fernand Dehaitre, Paris).

pare it without creases or holes, and to line it. Often the final success in finishing depends on this initial preparation. The water mangle is also constructed with 4, 5, 6, or 7 rolls for finishing white articles. The water mangle can be arranged for several passages through the machine chasing and

provided with a drying roll, friction, etc. The rolls are made, according to the use they are to be put, of sycamore wood, compressed sawdust, compressed cotton waste, coconut fibre, jute cloth, etc. The metal rolls are all of bronze or lined with bronze jackets. They are heated in certain cases.

CHAPTER VII.

LIME-BOILING.

Treatment Preliminary to Lime-Boil—Grey Wash.—In the modern process of *washing after singeing*, the pieces, guided by pot eyes and drawn by the bowls of the washing machine, pass directly from the singe house to the adjacent bleach house, where after passing through the *grey washing machine* they are piled on the floor by a boy, aided by a stick. In this position they generally soften in the pile overnight, but such treatment is, not indispensable. The pieces, up to this point, in open width, are now in rope or chain form, which they retain through the whole sequence of operations, that is, until they are opened out for drying; that is to say, unless they are to be passed through Huillards' open-width keir. This first washing is sometimes dispensed with, and the grey fabrics pass directly from the singe into the liming machine and thence into the lime-boiling keir.

If this washing before the lime-boil be not indispensable yet it is most advantageous, more especially when working with a small scale washing machine. The rationale of grey washing consists in so far cleansing the cloth by eliminating some of the size and filling and in moistening the cloth to such an extent that it is now in a better condition for absorbing the milk of lime. At one time it was usual to steep the grey cloth in cold water for two or three days and then to pass them through a washing machine previous to liming, but this time-consuming process, termed rot steeping, is now almost obsolete in Great Britain. During the steeping the starch in the size was rendered soluble by the putrefactive fermentation and could thus be readily washed out. The cloth

was, however, very liable to be tendered, the more so if bran was used in the steep to increase the energy of fermentation, which then became so energetic as to attack not only the impurities but even the fibre of the cotton cloth itself.

Milk of Lime Lyes.—The use of lime for bleaching fabrics is of very ancient date. Xenophon (445-335 B.C.) narrates that a ship loaded with linen fabrics and with lime for the purpose of bleaching them perished within sight of Marseilles, because a leak was struck in the bunker where the lime was stowed. In the Middle Ages the rules of the bleaching trade guilds forbade the use of lime. Even now many bleachers will not use it, for fear of injuring or tendering the fabrics. However, the use of lime may be regarded as attended with no risk if suitable precautions be taken. The process is cheap as the price of lime is low. The fabrics so treated preserve their white colour better in the shop, and have less tendency to become yellowish.

Choice of Lime.—A well-burnt fat lime is to be preferred containing no iron and as white as possible. It is better to stow freshly burnt lime, out of contact with the air, until the moment it is to be used. Some like to have lump quicklime, which they slake as required for use; others find the use of powdered lime more convenient. There is no difficulty in using lime under either of these two forms; what is important is to take care that it does not carbonate in contact with the air. Lime, therefore, should not be slaked too long before using, as it absorbs carbonic acid from the atmosphere, whereby carbonate of lime is formed, and this is useless for liming cloth. In selecting a quicklime, badly burnt pieces, clinkers, stones, etc., should be guarded against.

Diffusing the Lime in Water.—A special wrought-iron tank should be provided for diffusing the slaked lime through water. For this purpose the tank is filled with water, and a cage fitted with a sieve is suspended in the interior. The lime is run into this cage and stirred with a piece of wood so as to reduce it to paste, and thus enable it to pass through the gauze of the sieve. All the stones, clinkers, and other impurities

remain in the cage and sieve. By passing the lime through the sieve, the meshes of which should not be more than 2 square millimetres, we may be certain that no unslaked particles remain which would burn the fabrics if they came in contact with them in the state of quicklime. If the milk of lime be allowed to stand a certain time before use it deposits at the bottom. Care must therefore be taken to stir the tank well up before sending the milk of lime on to the liming

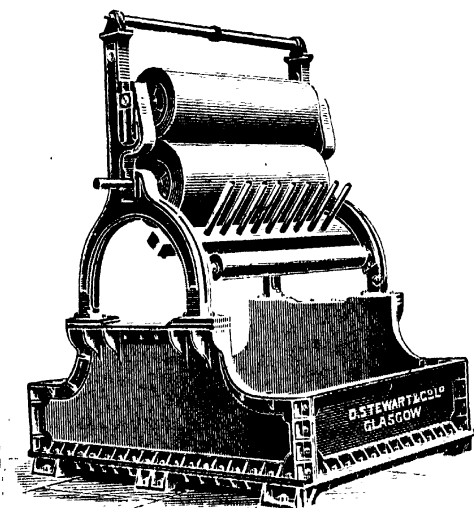


FIG. 16.—Liming machine (D. Stewart & Co., Glasgow).¹

machine or the lime-boiling keir. The supply pipe should be run into the bottom of the trough of the liming machine and not over the top, in which latter case it may splash on to the cloths and lead to overliming, which is not to be desired on account of its liability to rot the cloth.

The tank in which the lime is diffused through water is generally placed in the interior of the bleach works, and in proximity to the fabrics. When the quicklime is being carried about and when it is being thrown into the cage to be slaked

A similar type of machine is used for saturating fabrics with chemick.

and diffused, great care must be taken to guard against lime dust falling on the fabrics in proximity, for it would seriously injure them.

Quantity of Lime to Use.—The quantity of lime to use varies from 3 to 12 per cent of lime on the weight of the cloth. The quantity to use is indicated in the different examples of treatment. The bleacher will himself determine this quantity according to the degree of whiteness which he desires to obtain, and according as he has greater or less fear of injuring the fabrics.

DENSITY OF MILK OF LIME OF VARIOUS STRENGTHS.

Degrees Baumé	Densities.	CaO in 100 lb.	CaO in 10 gals. in lb.	Degrees Baumé.	Densities.	CaO in 100 lb.	CaO in 10 gals. in lb.
10	1'074	10'6	13'3	22	1'180	16'5	24'0
12	1'091	11'6	15'2	24	1'199	17'2	25'3
14	1'107	12'7	17'0	26	1'220	17'8	26'3
16	1'125	13'7	18'9	28	1'241	18'3	27'0
18	1'142	14'7	20'7	30	1'262	18'7	27'7
20	1'161	15'7	22'4				

To prevent this mishap the lime may be slaked in a cistern outside the bleach works proper, a paste being thus obtained which may be carried about without danger. To test the effect of different proportions of lime several lots of cloth, each $1\frac{1}{4}$ tons, were boiled by Hummel for ten hours with (a) 100 lb. ; (b) 150 lb. ; (c) 160 lb. ; (d) 200 lb. ; (e) 260 lb. lime, in the usual way. The various lots were then soured, washed, boiled with soda ash, chemicked, soured, and washed, as usual. From each lot a small piece of the cloth was taken and dyed in a madder bath for two and three-quarter hours, boiling during the last quarter of an hour. All the fents became dyed a pink shade ; b, c, d, e, were less tinged than a, there being little difference between c, d, and e. *Result : use 150 to 160 lb. lime per 2800 lb. cloth.* Experience shows that light goods require less lime than this quantity. Cloth boiled on the small scale with lime for five, ten, twenty hours, and treated as before,

showed in subsequent dyeing no difference; hence ten hours' boil may be deemed sufficient for a keir full of cloth, using low pressure (Hummel).

The amount of lime used, says Hurst, varies in different bleach works, and there is no rule on the subject; about 5 lb. to 7 lb. of dry lime to 100 lb. of cloth may be taken as a fair quantity to use.

According to Ure, 1 lb. of lime, previously made into a creamy consistency and passed through a sieve, is used for every 30 or 40 lb. of cloth, according to its colour and texture; and this cream mixed with more water is interstratified with the pieces, as they are laid regularly in the vessel. Whenever this is stocked with goods, all their interstices are filled up with water. After the lime bucking the cloth is transferred to the dash-wheel.

When in the milk of lime boil there is too much of this caustic earth, or when it is poured in on the top of the goods, they are apt to suffer damage. The milk of lime should be introduced from beneath into the under compartment of the bucking apparatus.

Duration of the Lime-Boiling Process.—This will vary from eight to ten hours, and during this time care must be taken that the lye is kept in continual circulation. If the keir be a closed one, by which the temperature can be brought to 110° C. (230° F.), the duration of the boiling can be shortened a little, but if the boiling be carried on under the normal atmospheric pressure, the boiling should never last less than eight to ten hours.

Washing after Lime-Boil.—When the boiling is finished the lime water is run off. It is a good practice to run cold water on the fabrics so as to give them a first wash in the keirs, which takes away a portion of the lime. If it be necessary to leave the fabrics for some time before washing them, the keir must be filled with water so as to prevent the fabrics from drying whilst impregnated with lime.

N.B.—Soda lyes must not be made in the tank in which the lime is slaked and diffused, nor should lime keirs be used

for boiling with soda lye, at least not without having washed them very clean. The remaining lime would convert the carbonate of soda into caustic soda, and the bleacher would obtain a much stronger lye than that which he counted on using. The lime-boil has for its object the removal or rather the saponification of the resinous and fatty matters present in the grey cloth, either naturally or which have been added in the process of weaving, or have got upon the cloth accidentally during the processes of spinning and weaving. With these bodies the lime forms insoluble lime soaps; these remain in the cloth, but in a form easily decomposable and removable by treatment with acids and washing. Soda or potash is not nearly so good for this first boiling as lime—for what reason is somewhat uncertain, but probably because they form with the grease in the cloths soluble soaps, which might float about the keir and accumulate in places where they are not required and thus lead to stains, whereas the insoluble lime soap remains where it was formed. The lime also seems to attack the natural colouring matter of the cotton, and although the colour of the limed cloth is darker than before boiling, yet the nature of the colour is so altered that it is more easily removed in the after processes.

Keirs for Lime-Boiling.—These vessels may be of wood, cast iron, or wrought iron. Wooden vats are now but seldom made. Cast-iron vats last the longest, but they are dearer than wrought-iron ones. The latter do not keep in the heat so well, but they may be lined inside with wooden staves, which at the same time prevent the fabrics from coming in contact with the iron. Rust is to be feared when the keir is new, but in the long run the iron becomes covered with a coat of lime, which preserves it against further oxidation. It is very important that these keirs should be provided with a lid, even if it only be a wooden one simply placed on the keir, because a great loss of heat is thus prevented. Inside the keir is a 4-inch pipe for the circulation of the lye, and it must be wide enough not to become choked up by calcareous deposits. The steam, acting after the principle of Giffard's injector,

causes the lye to circulate at the same time that it is maintaining the heat. A conical hood fixed above the pipe causes the lye to spread in a fan-shaped form. The pipe must be placed in the centre of the keir, so that the lye may spread equally on all sides. But if the keir be small, the pipe is placed at the side, so as not to interfere with the proper laying down or piling of the fabrics in the keir.

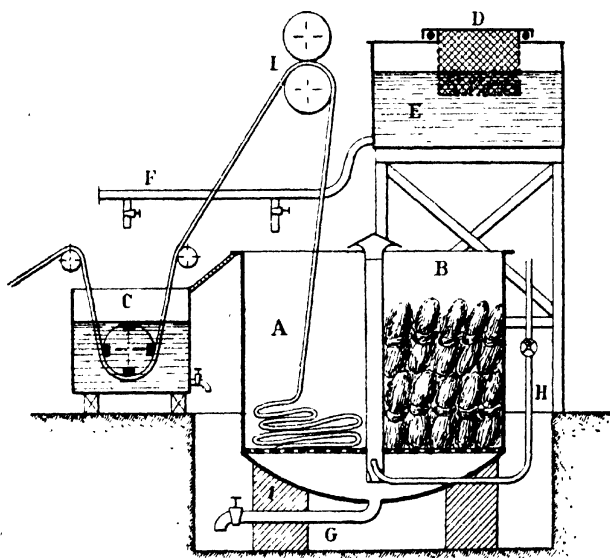


FIG. 17.—Liming machine. Lime-boiling keir.

A, Piling in bands; B, Piling in bundles; C, Saturating vat; D, Cage for sifting the lime; E, Tank for preparing milk of lime; F, Pipe for distributing milk of lime; G, Discharge pipe; H, Steam pipe; I, Rollers.

The Piling of the Fabrics in the Keir.—Lime has some difficulty in penetrating through the fabrics; the most suitable means must therefore be taken to facilitate this penetration. If the fabrics be laid in bundles, the cord is first slackened. The bundles are then placed in an upright position. When the first tier has been laid the water and milk of lime are run in, and the fabrics are tramped on to impregnate them well.

Then a second tier is laid, and the same operation gone through. The keir filled, it is curbed or lashed so that the fabrics cannot rise up. The lashing generally consists in placing above the fabrics a thick rope net fixed on a circle, the whole supported by several cross pieces. Planks may also be used, supported by cross pieces. Care must be taken to prevent the fabrics rising out of the liquid, and being thus exposed to the air or to steam. When the fabrics are laid in a band as in A, Fig. 17, it is advisable to first of all impregnate them with lime, by causing them to pass, by the aid of propelling rollers, I, through a tank C, containing milk of lime and water. A man, with the help of a stick, arranges the folds regularly in the vat. If it be found too complicated to pass the pieces through a saturation tank, the work is so arranged that they fall into the keir at the same time as the milk of lime is being delivered into A through the pipe F, and that the man who arranges them stamps on them with his feet in such a manner that they are well impregnated. This latter method is equally good, but it does not allow of so many pieces being laid in the keir. Fig. 17 shows the different methods of laying the pieces in the keir.

CHAPTER VIII.

CAUSTIC AND CARBONATED ALKALI.

Alkali and Alkaline Carbonate.—Preparation of Sodium Carbonate.—The raw material which serves as a point of departure in the manufacture of sodium carbonate is *common salt* (sodium chloride). There are two processes which may be used to convert common salt into sodium carbonate: (1) the Leblanc process; (2) the Solvay (Brunner Mond) process.

The Leblanc process, invented in 1792, consists in converting common salt into sulphate of soda, then in heating a mixture of this sulphate with limestone and coal on the sole of a reverberatory furnace. The crude product is a mixture of carbonate of soda soluble in water and calcium sulphide very slightly soluble in that liquid. This difference in properties enables the carbonate to be isolated. The mixture is treated by water so as to obtain solutions termed *leys* and residues termed *cinders*.

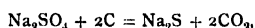
Soda Ash, Na_2CO_3 , *Molecular Weight* 106.—This is the trade name of the product which the *leys* yield on evaporation by the aid of heat. It is an impure carbonate of soda utilized as such by certain industries.

Soda Crystals, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, *Molecular Weight* 286.—A suitably concentrated solution of soda ash in luke-warm water yields on cooling almost pure crystals of the above composition, the impurities present in the soda ash being, in presence of a sufficiency of water, dissolved in the mother liquor. The insoluble impurities are also eliminated.

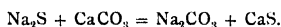
Theory and Stages of the Leblanc Process.—The mixture utilized in the Leblanc process is in the following proportions:—

Sodium sulphate	-	-	-	-	-	200
Calcium carbonate	-	-	-	-	-	200
Coal	-	-	-	-	-	106

The theory of the reaction is that the carbon reduces the sulphate to the condition of sulphide,



then the sodium sulphide and the carbonate react together to yield sodium carbonate and calcium sulphide,



Very diverse types of plant are used to carry on the process, revolving furnaces for instance. This furnace consists essentially of a large iron cylinder movable around its axis and lined inside with fire bricks. The mixture brought by a wagon is fed into the cylinder where it is heated by a strong flame from the furnace. When the mass is fused so as to mix it intimately the cylinder is revolved at the rate of one revolution in three minutes until the reaction is finished, when the contents of the cylinder are run into a wagon.

Ammonia Soda.—For some thirty years and more carbonate of soda has been prepared on a commercial scale by utilizing a method rendered a practical one by M. Solvay. The reaction is very simple. If a current of carbonic acid be passed into a solution of common salt to which ammonia has been added, bicarbonate of soda slightly soluble in water is deposited, and ammonium chloride remains in solution in the liquor. The bicarbonate of soda thus obtained is heated to dull redness, by which it is converted to neutral carbonate.

Theory of the Reaction.—The carbonic acid in presence of a solution of ammonia yields bicarbonate of ammonia,



but the latter in presence of chloride of sodium yields bicarbonate of sodium and ammonium chloride. The half of the carbonic acid is liberated during the calcination of the bicarbonate. It re-enters into the manufacture. The other half of the carbonic acid required is provided by the burning of lime-

stone, and the lime which results from that operation by reacting on the chloride of ammonia is used to regenerate the ammonia gas.

THE VALUATION OF CAUSTIC AND CARBONATED ALKALI (SODA) AND GENERAL INFORMATION REGARDING THESE BODIES.

Object of Alkalimetry.—The object of alkalimetry in the case of the chemical control of bleach works is to ascertain the strength of any soda lye. In France soda was, until quite recently, generally valued by the Descroizilles degree. The Descroizilles degree represents the number of parts by weight of monohydrated sulphuric acid which can be neutralized by 100 parts by weight of the sample to be tested.

Titration of Carbonate of Soda.—Pure carbonate of soda Na_2CO_3 titrates 92.45° Descroizilles, that is,

$$100 \times \frac{98}{106} \text{ molecular weight of sulphuric acid,}$$

" " " carbonate of soda,

in other words, 100 parts of pure carbonate of soda neutralize 94.2 parts of sulphuric acid. To titrate a soda ash by Descroizilles standard, the method given below must be followed. (1) *Sampling.*—The sample ought to be taken from the centre of the barrel by means of the sampling tool—a sort of cheese taster—because soda which has been in contact with the sides is often a little moist. If the soda has been exposed to moisture the sample must be dried by heating it strongly. (2) *Standard Acid.*—The soda is titrated by a standard acid, which is so adjusted that 92.45 cubic centimetres of this dilute acid exactly saturates 10 grammes of pure dry carbonate of soda. This standard acid is prepared by diluting 100 grammes of concentrated sulphuric acid 66° Baumé, specific gravity 1.84 , with distilled water to 1 litre. The liquid must be tested by titrating a chemically pure sample of carbonate of soda made in the laboratory, and which in accordance with what has been said ought to titrate 92.45° . The acid is con-

EQUIVALENTS OF BRITISH AND CONTINENTAL
ALKALIMETRICAL DEGREES.

Descroizilles Degrees H_2SO_4 .	German Degrees Na_2CO_3 .	Gay-Lussac Degrees Na_2O	L'pool Degrees ¹ Na_2O .	NaHO .
0°79	0°85	0°5	0°51	0°65
1°58	1°71	1°0	1°01	1°20
2°37	2°56	1°5	1°52	1°94
3°16	2°42	2°0	2°03	2°58
3°95	4°27	2°5	2°54	3°23
4°74	5°13	3°0	3°04	3°87
5°53	5°98	3°5	3°55	4°52
6°32	6°84	4°0	4°05	5°16
7°11	7°69	4°5	4°56	5°81
7°90	8°55	5°0	5°06	6°45
8°69	9°40	5°5	5°57	7°10
9°48	10°26	6°0	6°08	7°74
10°27	11°11	6°5	6°59	8°39
11°06	11°97	7°0	7°09	9°03
11°85	12°82	7°5	7°60	9°68
12°64	13°68	8°0	8°10	10°32
13°43	14°53	8°5	8°61	10°97
14°22	15°39	9°0	9°12	11°61
15°01	16°24	9°5	9°63	12°26
15°81	17°10	10°0	10°13	12°90
16°60	17°95	10°5	10°64	13°55
17°39	18°81	11°0	11°14	14°19
18°18	19°66	11°5	11°65	14°84
18°97	20°52	12°0	12°17	15°48
19°76	21°37	12°5	12°68	16°13
20°55	22°23	13°0	13°17	16°77
21°34	23°08	13°5	13°68	17°32
22°13	23°94	14°0	14°18	18°06
22°92	24°79	14°5	14°69	18°71
23°71	25°65	15°0	15°19	19°35
24°50	26°50	15°5	15°70	20°00
25°29	27°36	16°0	16°21	20°64
26°08	28°21	16°5	16°73	21°29
26°87	29°07	17°0	17°22	21°93
27°66	29°92	17°5	17°73	22°58
28°45	30°78	18°0	18°23	23°22
29°24	31°63	18°5	18°74	23°87
30°03	32°49	19°0	19°25	24°51
30°82	33°34	19°5	19°76	25°16
31°61	34°20	20°0	20°26	25°80
32°40	35°05	20°5	20°77	26°45
33°19	35°91	21°0	21°27	27°09
33°98	36°76	21°5	21°78	27°74
34°77	37°62	22°0	22°29	28°38
35°56	38°47	22°5	22°80	29°03
36°35	39°33	23°0	23°30	29°67
37°14	40°18	23°5	23°81	30°32
37°93	41°04	24°0	24°31	30°96
38°72	41°89	24°5	24°82	31°61
39°51	42°75	25°0	25°33	32°25
40°30	43°60	25°5	25°83	32°90
41°09	44°46	26°0	26°34	33°54

¹ Taking 24 as the atomic weight of sodium, the English or Newcastle degree corresponds with Gay-Lussac's.

EQUIVALENTS OF BRITISH AND CONTINENTAL
ALKALIMETRICAL DEGREES—*continued*.

Descroizilles Degrees H ₂ SO ₄ .	German Degrees Na ₂ CO ₃	Gay-Lussac Degrees Na ₂ O.	L'pool Degrees ¹ Na ₂ O.	NaHO.
41°88	45°31	26°5	26°85	34°19
42°67	46°17	27°0	27°35	34°83
43°46	47°02	27°5	27°86	35°48
44°25	47°88	28°0	28°36	36°12
45°04	48°73	28°5	28°87	36°77
45°83	49°59	29°0	29°38	37°41
46°62	50°44	29°5	29°89	38°06
47°42	51°29	30°0	30°39	38°70
48°21	52°14	30°5	30°90	39°35
49°00	53°00	31°0	31°41	40°00
49°79	53°85	31°5	31°91	40°65
50°58	54°71	32°0	32°42	41°29
51°37	55°56	32°5	32°92	41°94
52°16	56°42	33°0	33°34	42°58
52°95	57°27	33°5	33°94	43°23
53°74	58°13	34°0	34°44	43°82
54°53	58°98	34°5	34°95	44°52
55°32	59°84	35°0	35°46	45°16
56°11	60°69	35°5	35°96	45°81
56°90	61°55	36°0	36°47	46°45
57°69	62°40	36°5	36°98	47°10
58°48	63°26	37°0	37°48	47°74
59°27	64°11	37°5	37°99	48°39
60°06	64°97	38°0	38°50	49°03
60°85	65°82	38°5	39°00	49°68
61°64	66°68	39°0	39°51	50°32
62°43	67°53	39°5	40°02	50°97
63°22	68°39	40°0	40°52	51°60
64°01	69°24	40°5	41°03	52°25
64°81	70°10	41°0	41°54	52°90
65°60	70°95	41°5	42°04	53°55
66°39	71°81	42°0	42°55	54°19
67°18	72°66	42°5	43°06	54°84
67°97	73°52	43°0	43°57	55°48
68°76	74°37	43°5	44°07	56°13
69°55	75°23	44°0	44°58	56°77
70°34	76°08	44°5	45°08	57°32
71°13	76°95	45°0	45°59	58°06
71°92	77°80	45°5	46°10	58°71
72°71	78°66	46°0	46°60	59°35
73°50	79°51	46°5	47°11	60°00
74°29	80°37	47°0	47°62	60°64
75°08	81°22	47°5	48°12	61°29
75°87	82°07	48°0	48°63	61°93
76°66	82°93	48°5	49°14	62°58
77°45	83°78	49°0	49°64	63°22
78°44	84°64	49°5	50°15	63°87
79°03	85°48	50°0	50°66	64°50
79°82	86°34	50°5	51°16	65°15
80°61	87°19	51°0	51°67	65°80
81°40	88°05	51°5	52°18	66°45
82°19	88°90	52°0	52°68	67°09

¹ Taking 24 as the atomic weight of solution.

EQUIVALENTS OF BRITISH AND CONTINENTAL
ALKALIMETRICAL DEGREES—*continued*.

Descroizilles Degrees H_2SO_4 .	German Degrees Na_2CO_3 .	Gay-Lussac Degrees Na_2O .	L'pool Degrees ¹ Na_2O .	NaHO
82.98	89.76	52.5	53.19	67.74
83.77	90.61	53.0	53.70	68.38
84.56	91.47	53.5	54.20	69.03
85.35	92.32	54.0	54.71	69.67
86.14	93.18	54.5	55.22	70.32
86.93	94.03	55.0	55.72	70.96
87.72	94.89	55.5	56.23	71.6
88.52	95.74	56.0	56.74	72.25
89.31	96.60	56.5	57.24	72.90
90.10	97.45	57.0	57.75	73.54
90.89	98.31	57.5	58.26	74.19
91.68	99.16	58.0	58.76	74.83
92.47	100.02	58.5	59.27	75.48
93.26	100.87	59.0	59.77	76.12
94.05	101.73	59.5	60.28	76.77
94.84	102.58	60.0	60.79	77.40
95.63	103.44	60.5	61.30	78.05
96.42	104.30	61.0	61.80	78.70
97.21	105.15	61.5	62.31	79.35
98.00	106.01	62.0	62.82	80.00
98.79	106.86	62.5	63.32	80.65
99.58	107.72	63.0	63.83	81.30
100.37	108.57	63.5	64.33	81.94
101.16	109.43	64.0	64.84	82.58
101.95	110.28	64.5	65.35	83.23
102.74	111.14	65.0	65.85	83.87
103.53	111.99	65.5	66.36	84.52
104.32	112.85	66.0	66.87	85.17
105.11	113.70	66.5	67.37	85.82
105.90	114.56	67.0	67.88	86.47
106.69	115.41	67.5	68.39	87.12
107.48	116.27	68.0	68.89	87.74
108.27	117.12	68.5	69.40	88.39
109.06	117.98	69.0	69.91	89.03
109.85	118.83	69.5	70.41	89.67
110.64	119.69	70.0	70.92	90.32
111.43	120.53	70.5	71.43	90.97
112.23	121.39	71.0	71.93	91.61
113.02	122.24	71.5	72.44	92.26
113.81	123.10	72.0	72.95	92.90
114.60	123.95	72.5	73.45	93.55
115.39	124.81	73.0	73.96	94.19
116.18	125.66	73.5	74.47	94.84
116.95	126.52	74.0	74.97	95.49
117.76	127.37	74.5	75.48	96.13
118.55	128.23	75.0	75.99	96.77
119.34	129.08	75.5	76.49	97.42
120.13	129.94	76.0	77.00	98.06
120.92	130.79	76.5	77.51	98.71
121.71	131.65	77.0	78.01	99.35
122.50	132.50	77.5	78.52	100.00

¹ Taking 24 as the atomic weight of sodium.

centrated or diluted until it gives exactly this result. The standard acid sold by dealers is not always exact. (3) *Mohr's Burette*.—The instrument by which titrations are made is known as Mohr's burette, and consists of a tube capable of holding 100 centimetres of standard acid. The tube is graduated and each cubic centimetre corresponds to 1° Descroizilles. Ten grammes exactly of the sample of soda to be tested is weighed out and placed in a glass beaker or a porcelain basin, and is dissolved in the hot in about 200 cubic centimetres of distilled water, to which a few drops of tincture of litmus have been added, and then a drop of normal acid to neutralize the alkalinity of the tincture, so that the liquid has a faint reddish tinge. The operator satisfies himself that he has not added too much acid by spotting a drop on a strip of litmus paper by means of a glass rod dipped in the solution.

He then reads off the tube the number of cubic centimetres of test acid used. This figure represents the strength of the soda in Descroizilles degrees. All that has to be done in order to ascertain the Gay-Lussac and the English degree is to consult the table. The Gay-Lussac degree expresses the percentage strength of the alkali in anhydrous caustic soda, Na_2O , calculated from the atomic weight, 62. The English degree also indicates the percentage strength of the alkali in anhydrous soda, Na_2O , but calculated from the old molecular weight, 64. Newcastle alkali is sold on Gay-Lussac standard—atomic weight, 62; Liverpool alkali on the so-called English standard—molecular weight, 64. For an interesting discussion on the economical influences of this variation in standard of valuation, see "Journal of Society of Chemical Industry".

Explanation of the Table.—The first column gives the Descroizilles degree, that is to say, the number of parts by weight of monohydrated sulphuric acid (66° Baumé) which are neutralized by 100 parts by weight of the sample. In fact the standard acid is made up so that each cubic centimetre contains $\frac{1}{10}$ of a gramme of sulphuric acid (66° Baumé) and the sample being tested weighs 10 grammes or $100 \times (\frac{1}{10})$

of a gramme). The number of cubic centimetres used in neutralizing the alkali therefore gives, in accordance with the definition of the Descroizilles degree, the number of parts by weight of sulphuric acid which saturate 100 parts of carbonate of soda. So as not to use up too much test acid, 5 grammes are titrated instead of 10, and the number of cubic centimetres of test acid used is multiplied by 2. The second column gives the percentage of carbonate of soda. This percentage equals the Descroizilles degree divided by 92.47 multiplied by 100. In fact 92.47 parts of sulphuric acid saturate 100 parts of pure carbonate of soda. If a sample requires N parts of acid to saturate 100 parts of soda, it is evident that the relation or comparative strength of the carbonate of soda in the sample to that of the pure carbonate will be $\frac{N}{92.47}$, and to get the percentage the result is multiplied by 100. The percentage strength is therefore equal to the Descroizilles degree $\times \frac{100}{92.47}$, or 1.081. The third column gives the Gay-Lussac or British degree or the percentage strength in anhydrous soda (Na_2O). It is calculated from the percentage of carbonate of soda by multiplying that percentage by $\frac{62}{106}$, or the Descroizilles degree by $(\frac{62}{106} \times \frac{1}{92.47} \times 100) = 0.632$. In fact the elements of carbonate of soda have as equivalents—



from which it follows that the weight of sodium oxide contained in a certain weight of carbonate of soda is equal to the weight of the latter multiplied by $\frac{62}{106}$.

Use of Di-methyl Orange as an Indicator in place of Litmus.

—The use of litmus as a reagent presents this inconvenience, that it is coloured a wine-red by carbonic acid. The operation must therefore be performed at the boiling temperature. With di-methyl orange the titration may be done in the cold, as that indicator is insensible to carbonic acid. It colours an alkaline solution yellow and an acid one rose-red. To seize the exact moment of transition from yellow to rose

only a very weak yellow coloration must be given to the alkaline liquid to be tested. The "Agenda du Chimiste" gives the following instructions regarding this substance: "A test solution of di-methyl aniline orange or Poirier's heliantine is made by dissolving 1 gramme of this substance in a litre of cold water. Mineral acids turn it red, even sulphurous acid; but organic acids, including oxalic acid, produce no change of colour, neither do carbonic acid nor sulphuretted hydrogen. Four drops of this solution are added for every 100 cubic centimetres of liquid to be titrated, which ought to be feebly but decidedly coloured. It must never be used in hot solutions. It is insensible to carbonic acid, and succeeds in the presence of ammonia, but the quantity of acid necessary to produce the neutral shade of liquid must be deducted."

Titration of Weak Carbonate of Soda Lyes.—In the titration of weak lyes, that is to say, those marking about 1° to 3° Baumé, it is preferable to use a weaker test acid than the normal alkalimetric test acid (No. 1). This weaker test acid (No. 2) is made by diluting 10 grammes of sulphuric acid, 66° Baumé, with distilled water to 1 litre. Ten grammes of lye are titrated, the number of cubic centimetres divided by ten gives the Descroizilles degree of the lye in question. When lyes are being tested it is more convenient to test a given volume of lye than a given weight. Ten cubic centimetres therefore of the lye are taken for titration instead of 10 grammes, and the results expressed by volume and not by weight.

Solution of Certain Problems Relating to Caustic and Carbonated Alkali. First Problem.—Given a solution of carbonate of soda saturated by N cubic centimetres of normal alkalimetric test acid, to find how much carbonate of soda this represents in grammes. 92.45 cubic centimetres of normal alkalimetric test acid saturate 10 grammes of pure carbonate of soda, and the following proportion gives the number of grammes X which are saturated by N cubic centimetres of the alkalimetric test acid:—

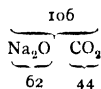
$$\frac{X}{10} = \frac{N}{92.45} \quad X = \frac{10 N}{92.45} = \frac{N}{9.245}$$

i.e. in the quantity of lye tested there are X grammes of carbonate of soda.

Second Problem.—Given a solution of carbonate of soda saturated by N centimetres of normal alkalimetical test acid, to find how much caustic alkali (anhydrous sodium oxide Na_2O) this represents in grammes. 92.47 cubic centimetres of test acid saturate 10 grammes of carbonate of soda (Na_2CO_3), or 10 grammes $\times \frac{62}{106}$ of caustic alkali (Na_2O). N cubic centimetres of test acid saturate X grammes of carbonate of soda or Y grammes of caustic alkali Na_2O , and the value of Y may be obtained:—

$$Y = X \frac{62}{106} = \frac{N \times 10 \times \frac{62}{106}}{92.47} = \frac{N}{10} \times 0.632.$$

Observe that $N \times 0.632^\circ$ represents the Gay-Lussac degree and the Newcastle degree, and is found in the table. The equivalents in weights of the elements of carbonate of soda are:—

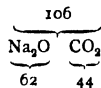


The weight Z of sodium oxide (Na_2O) contained in any given weight (P) of carbonate of soda may be found by the following proportion:—

$$\frac{Z}{62} = \frac{P}{106} \quad Z = P \times \frac{62}{106} = P \times 0.585.$$

Third Problem.—What weight X of quicklime is required to transform a given weight of carbonate of soda P from carbonate of soda into carbonate of lime, with liberation of free caustic soda?

The equivalent of carbonate of soda being



that of quicklime being



Caustic Soda.—This is the trade name for sodium hydrate Na_2O , H_2O (NaHO). The caustic soda is used for lyes by itself, or mixed with carbonate of soda, and then this mixture is termed in America sal soda. Caustic soda being much more energetic in its action than carbonate of soda or sal soda certain precautions must be taken in its use; amongst others, it must not be allowed to act on the fabrics in contact with the air, or the fabrics will be completely burnt in those parts. This was found to be the result of observations made by M. Koechlin in Alsace—observations the correctness of which has been verified by many others. Caustic soda is advantageously used in Mather and Platt's keir, but it may be used in all kinds of keirs provided care and attention be taken to wash the fabrics thoroughly before sending them to the bleaching green. Caustic soda is met with in commerce in the solid state; it is sent out in wrought-iron cylinders. As it is very hard, it is broken with a sledge-hammer. The workmen should use spectacles to protect the eyes from its corrosive action.¹ The soda is dissolved in the proportion of 333 to 335 grammes per litre of water (say 3 lb. to the gallon), and a lye is obtained marking 33° to 35° Baumé at 15° C. This solution is boiled for about an hour, during which time a great deal of impurity floats to the top in the form of scum, which is removed by a wooden rake. This concentrated lye is used in the preparation of lyes for bucking or lye-boiling by the addition thereto of the necessary quantity of water to reduce it to the desired strength. The strength of these lyes varies from 0.5° to 2° and even 3° Baumé. Caustic soda strongly attacks iron and copper when concentrated. For making a solution of 33° Baumé it is best to use a cast-iron tank, with cast-iron stop-cocks. Cast iron resists alkali far better than copper, and, moreover, is much cheaper. Caustic soda (Leblanc) (110° Descroizilles 70 per cent caustic) has the following composition :—

¹ Caustic soda in coarse powder is now an article of commerce. It is much to be preferred to the solid, the breaking up of which is dangerous. Remedy for caustic soda in eye: bathe the eye with vinegar or highly dilute acetic acid.

ANALYSIS OF COMMERCIAL CAUSTIC SODA 110° DESCROIZILLES.

	Per Cent.
Sodic hydrate (NaHO) - - - - -	89.600
„ carbonate (Na_2CO_3) - - - - -	2.481
„ chloride (NaCl) - - - - -	3.919
„ sulphate (Na_2SO_4) - - - - -	3.419
„ sulphide (Na_2S) - - - - -	0.025
„ silicate (Na_2OSiO_2) - - - - -	0.304
	<hr/> 99.748 <hr/>

These proportions correspond to—

	Per Cent.
Sodic anhydride (Na_2O) - - - - -	69
Combined water - - - - -	20
Impurities - - - - -	11
	<hr/> 100 <hr/>

Remark.—It is very necessary to realize the exact meaning of the terms used to denote the strength of an alkali or an alkaline liquid, whether in degrees Descroizilles or otherwise, and to be able to convert these terms into the actual percentage of soda. In a case like the present this may be done in the following way: 92.45 cubic centimetres of normal alkalimetric test acid saturates 10 grammes of carbonate of soda (Na_2CO_3) or 10 grammes $\times \frac{62}{106}$ of anhydrous soda, and the following proportion gives the number Y of cubic centimetres of the standard acid required to saturate 10 grammes of soda :—

$$\frac{Y}{92.47} = \frac{10}{10 \times \frac{62}{106}} \quad Y = 92.47 \times \frac{106}{62} = 158.06;$$

that is to say, if the caustic soda was pure and anhydrous its alkalimetric degree would be 158.06. Now its alkalimetric degree is 110, the proportion of carbonate of soda is therefore $\frac{110}{158.06} = 0.69$, as indicated previously.

Titration of Caustic Soda.—Caustic soda is titrated in the same way as carbonate of soda. Five or 10 grammes of the soda to be tested are taken and, using litmus as indicator, the number of half cubic centimetres or cubic centimetres of the standard acid required to saturate this quantity of soda are determined. These represent respectively the degree Descroizilles according as to whether 5 or 10 grammes of caustic

were taken. If the sample to be tested is entirely caustic there is no necessity to heat, since there is no disengagement of carbonic acid to redden the litmus. Di-methyl orange may also be used as indicator.

Titration of a Mixture of Carbonated and Caustic Alkali.—Very often the alkali to be tested does not consist solely of caustic soda or carbonate of soda, but is a mixture of both. It is useful to know the proportions in which the carbonate of soda and the caustic soda are mixed. This is determined in the following way.

Total Alkali.—The total alkali is determined by the method previously indicated, using litmus or di-methyl orange as indicator.

Caustic Alkali.—Poirier's blue, C.L.B., is employed as indicator in the titration of the caustic alkali, in virtue of the following properties. In presence of free alkalies it is red, and blue with alkaline carbonates and salts of weak acids. The number of cubic centimetres of standard acid required to convert the red alkaline solution to blue is determined. This figure gives the alkalinity due to caustic soda. As, on the other hand, the total alkali has been determined, the alkalinity due to carbonate of soda is found by difference.

Mixtures of Carbonated and Caustic Alkali.—The alkaline bodies sold in commerce under different names are mixtures of carbonated and caustic alkali, with a considerable amount of water and impurities. These products are sold according to their degree Descroizilles, with an indication of the amount of caustic present. Here is an example of this kind titrating 80° Descroizilles :—

	Per Cent.	
Soda	15.5	} NaHO
Combined water	4.5	
Carbonate of soda	59.0	
Impurities	21	
	<hr/> 100.0	

Note on a Process for Manufacturing Caustic Soda.—In certain cases it might be advantageous to prepare in the works

itself the caustic soda required, by the decomposition of carbonate of soda by lime. The following are the advantages and the disadvantages of this method of procedure.

Brunner Mond's soda ash contains:—¹

	Per Cent.
Anhydrous soda	58
Carbonic acid	41
Impurities	1
	<hr/> 100 <hr/>

Solid caustic soda 70 per cent contains:—

	Per Cent.
Anhydrous soda (Na ₂ O)	69'00
Combined water	20'00
Impurities	11'00
	<hr/> 100'00 <hr/>

Seventy-seven per cent caustic has now been on the market for over a decade. Soda ash costs about 3s. 6d. the cwt., and caustic soda, 77 per cent caustic, 10s. 6d. a cwt. It follows that the soda of the carbonate is paid for at the rate of

$$42d. \times \frac{112}{58} = 6s. 9d. \text{ per cwt.},$$

and that the soda of the 77 per cent caustic soda is paid for at the rate of

$$126d. \times \frac{112}{77} = 15s. 3d.,$$

which leaves a margin of 15s. 3d. - 6s. 9d. = 8s. 6d. If there be added the cost of the lime necessary to render the soda caustic, the margin will then be 15s. 3d. - 6s. 9d. + 1s. = 7s. 9d. = 7s. 6d. per cwt. It may here be remarked that the expense of labour and steam in caustifying the carbonate of soda is almost the same as that required to dissolve the caustic soda. The process of decarbonatation is very simple and the material costs but little. A certain quantity of soda ash is dissolved, then the corresponding quantity of quicklime is added, and the whole is kept boiling, by a steam pipe, for about two hours.

¹ See p. 89.

A sample of the liquid is filtered, and if a dilute acid produces no effervescence the caustification is complete; if, on the contrary, the liquid becomes cloudy on the addition of carbonate of soda there is an excess of lime. It is better to maintain always a slight excess of carbonate, which cannot be in any way injurious. The whole is allowed to stand, and the lime, now in the carbonated condition, falls to the bottom. The clear liquid is decanted and used in the preparation of lyes, the precipitated carbonate of lime is washed, allowed to settle, and the clear liquid again decanted, and this operation is repeated until the precipitate is exhausted of soda. The precipitate when sufficiently washed is thrown on the rubbish heap. Problem No. 3 shows, theoretically, that the lime ought to be $\frac{53}{100}$ of the carbonate, but in order to allow for impurities two-thirds of the weight of the carbonate of soda should be used. By the same process carbonate of soda lyes may be prepared containing a certain percentage of caustic soda (Na_2O). The proportions in which it is necessary to mix the carbonate of soda and the lime are indicated in problem No. 4; a little more quicklime being used so as to make allowance for impurities. The Irish manual recommends the use of a lye made by adding one-sixth of the weight of the lime to the carbonate. A lye is thus obtained 80 per cent of carbonated and 20 per cent of caustic alkali. It is necessary to allow the precipitated carbonate of lime time to settle, even although it has no injurious action on the fabrics. Carbonate of soda may be replaced by sulphate of soda. The soda is liberated by the lime which is transformed into sulphate of lime. The advantage of this substitution lies in the low price of sulphate of soda. On the other hand, the precipitated sulphate of lime deposits badly; numerous washings must be resorted to. Moreover, the soda obtained is not so pure in consequence of the impurities present in low-priced sulphate of soda.

Method of Preparing Caustic Soda by successively Enriching the Wash Liquors.—The method of exhausting the carbonate of lime muds by successive washings has the disadvantage of yielding lyes the strength of which progressively diminishes,

and requiring reservoirs of vast storage capacity to hold them. In order to obtain concentrated lyes of uniform strength the following method may be pursued.

Suppose five tanks are at our disposal : 1, 2, 3, 4, 5.

First Day.—Charge 1 with lime and soda ash, fill with water, agitate energetically, and let stand till morning.

Second Day (Morning).—Charge 2 with lime and soda ash. Syphon the clear liquid from 1 into 2. Fill 1 with water (first washing). Stir 1 and 2 energetically, and allow to stand.

Second Day (Evening).—Charge 3 with lime and soda ash.

Pass the clear liquid from 2 into 3.

” ” 1 ” 2.

Fill 1 with water (second washing). Stir 1, 2, and 3 energetically, and allow to stand.

Third Day (Morning).—Charge 4 with lime and soda ash.

Pass the clear liquid from 3 into 4.

” ” 2 ” 3.

” ” 1 ” 2.

Fill 1 with water (third washing). Stir 1, 2, 3, and 4 energetically, and allow to stand.

Third Day (Evening).—Charge 5 with lime and soda ash.

Pass the clear liquid from 4 into 5.

” ” 3 ” 4.

” ” 2 ” 3.

” ” 1 ” 2.

Fill 1 with water (fourth washing). Stir 1, 2, 3, 4, and 5 energetically, and allow to stand.

Fourth Day (Morning).—Syphon off the clear liquid from 5, which is a concentrated solution of caustic soda, and store it in reserve.

Pass the clear liquid from 4 into 5.

” ” 3 ” 4.

” ” 2 ” 3.

” ” 1 ” 2.

Stir 2, 3, 4, and 5 energetically, and allow to stand. The mud

of 1 having been washed four times is thrown on the rubbish heap.

Fourth Day (Evening).—Charge one with lime and soda ash.

Pass the clear liquid from 5 into 1.

” ” 4 ” 5.

” ” 3 ” 4.

” ” 2 ” 3.

Fill 2 with water, stir all the tanks, and allow to stand.

Fifth Day (Morning).—Syphon the clear liquid from 1 and store the concentrated caustic lye in reserve.

Pass the clear liquid from 5 into 1.

” ” 4 ” 5.

” ” 3 ” 4.

” ” 2 ” 3.

Stir 3, 4, 5, and 1, and allow to stand. Transfer mud of 2 to rubbish heap as sufficiently exhausted.

Fifth Day (Evening).—Charge 2 with lime and soda ash.

Pass the clear liquid from 1 into 2.

” ” 5 ” 1.

” ” 4 ” 5.

” ” 3 ” 4.

Fill 3 with water, stir all the tanks, and allow to stand.

Sixth Day (Morning).—Syphon the concentrated soda lye from 2, and continue the operations as on the preceding days.

Remark I.—Sixty kilogrammes of carbonate of soda and 40 kilogrammes of quicklime to 1000 litres of water are good proportions. Say 60 lb. and 40 lb. respectively to the 100 gallons. If the lime is slaked, 50 kilogrammes must be used.

Remark II.—The charge of lime and soda ash may be made as follows. A lime paste is made with a very small quantity of liquid, and beaten up in such a manner as to crush all the lumps. Then the reagent tank is filled with the liquid in the preceding tank, and the soda ash is dissolved by passing it through a sieve so as to crush all the lumps.

Remark III.—Mixing is done by hand with a shovel, or better still, by mechanical agitators fixed to each tank. If heat be used, the open steam, as it issues from the coil in the bottom of each pan, agitates the liquid to such an extent as to sufficiently mix the contents of the tank.

Remark IV.—The liquids are transferred from one tank to another by a pump, the suction and discharge tubes of which are made of india-rubber, so that they can be adapted in succession to each series of two tanks.

Determination of the Useful Duration of the Strength of Lyes.—*Revivifying Lyes.*—In order to determine how the operation is going on in lye-boiling, samples of the lye are taken from the keir from hour to hour, and the amount of soda absorbed in the interval by the fabrics is ascertained. It is found that after a certain time the strength of the lye does not diminish any further. When this happens, it is of no use to continue boiling any further. The lyes used in the first lye-boils are generally exhausted at the end of seven or eight hours' boiling, after which nothing remains but to run them off. But when the fabrics are nearly bleached they absorb but very little soda, in which case there is good reason for not running the lyes away. They should be stored for the boiling of fabrics in a less advanced stage of the bleaching process after they have been revivified by an addition of soda sufficient to replace that which was absorbed in the previous operation.

The experiments are made on 10 cubic centimetres of lye, and with deci-normal standard acid (i.e. normal acid diluted with ten times its volume of water).

As the lye has become of a brown colour, coloured indicators are of no use in deciding the point of neutralization. A strip of litmus paper is used instead. It is dipped from time to time into the liquid as the standard acid is being run in. The moment when the litmus paper passes from blue to red may thus be easily determined. If the lye contains carbonate, the carbonic acid remaining in solution must be expelled by boiling, otherwise it would turn the litmus paper red before the saturation point was reached.

CHAPTER IX.

LYE-BOILING: GENERAL METHODS.

Characteristics and Function of the Alkalies, etc., used to make Lyes for Use in Bleaching.

Caustic and Carbonated Alkalies.—The alkalies most commonly used are: (a) caustic soda; (b) carbonate of soda; and (c) a mixture of caustic and carbonated alkali, the most general proportion of which is 15 to 20 per cent of caustic soda and 80 to 85 per cent of carbonate of soda. Caustic soda is a very energetic solvent for coloured gummy and other substances, but it must be used with caution, so as not to attack the essential portion of the textile fibres. Above all, care must be taken not to allow it to act on the fabrics in contact with air, because they would be seriously damaged. The washings which follow lye-boiling (*débouillissage*) ought to be very thorough, especially if the fabrics are to be afterwards exposed on the bleaching green. If they retain the smallest proportion of caustic, it is quite sufficient to destroy them. The most suitable degrees of concentration of caustic lysés are given in the specifications for the different methods of bleaching. Carbonate of soda has the same solvent properties for gummy matters as caustic soda, but its action is much slower. There is little danger of injuring the fibre of the fabrics. When treating fabrics woven with various colours it is dangerous to use even weak caustic soda lysés, because certain colours do not stand their action. It is prudent only to use carbonate of soda lysés. Intermediate between caustic soda and carbonate of soda is a mixture containing 80 per cent of carbonate to 20 per cent caustic which is most frequently used in bleaching.

To work with pure caustic soda requires special plant and a very skilful staff of employees. If only carbonate be employed, operations must be multiplied, and still a proper white is not attained. Practice has demonstrated that the above mixture of caustic and carbonated alkali is safe enough in its use, and yields good results.

Caustic potash and carbonate of potash have the same properties as caustic soda and carbonate of soda. The compounds which they yield with the substances to be eliminated in bleaching are still more soluble in water than those of soda. They are less frequently used, however, on account of their higher price.

Lessive Phénix.—The “lessive Phénix,” very much used in boiling linen, contains silicate of soda. The “lessive Phénix” has been used for bleaching coarse Normandy sheeting with very good results; it has a more energetic action than carbonate of soda, and has not the same injurious effects as caustic soda. It answers very well for coloured fabrics.

Alkaline Sulphides, Sulphites, and Bisulphites.—Of all the solvents for the colouring principles of cotton and linen, the alkaline sulphides are the most energetic. Soda and potash rank but second. The difficulty in the use of alkaline sulphides is their destructive action on metallic pipes. Then again there is the decomposing action of chlorine, if the washings have not been thorough. Consequently they are not available, except when followed by a second washing with alkaline lye, or by an operation, which is not bleaching, with chlorine. The sulphides give a very pronounced white, but act strongly on the textile fibres. Some bleachers add successfully a little sulphite or bisulphite of soda to the soda lyes. The bisulphite of soda is added to the lye in the proportion of one-sixth of the weight of the caustic soda.

Strength of the Lyes. — Methods of Estimation. — The strength of the lyes depends on their concentration, which is proportional to the amount of salt dissolved per cubic metre. The strength is estimated in France by degrees Baumé. The degrees Baumé refer only to the density of the lye, but not to

its strength properly so called, that is to say, to its alkali-metrical strength, or the impurities which it may contain. To ascertain, for example, the real quantity of carbonate of soda or caustic soda contained in a lye, resort must be made to methods of chemical analysis. These methods are explained in a chapter devoted to alkalimetry. For the same quantity of alkali dissolved, the density varies with the nature of the alkali; it is therefore necessary to prepare a table indicating the number of kilogrammes of alkali which must be dissolved in 1000 litres of water, lb. per 100 gallons, so as to have the corresponding degree Baumé. In the following table the author gives those quantities for the salts most frequently used in France: (a) Solvay carbonate of soda 90° to 92° Descroizilles; (b) salt of soda, a mixture of caustic soda and carbonate of soda, 82° Descroizilles, containing 20 per cent of caustic soda; (c) caustic soda 112° Descroizilles. The indications go from 0° to 3° Baumé, because it is rare that more concentrated lyes are made.

NUMBER OF KILOGRAMMES OF DIFFERENT ALKALINE BODIES TO BE DISSOLVED IN 1000 LITRES, OR OF LB. IN 100 GALLONS, OF WATER TO OBTAIN AN ALKALINE LYE OF A CERTAIN DENSITY.

Degrees Baumé.	Weight in Kilogrammes per 1000 Litres, or in Lb. per 100 Gallons, of water.		
	Carbonate of Soda.	Soda Ash.	Caustic Soda.
0	0	0	0
0.5	4	4	3.25
1	8	8	6.75
1.5	12.5	12	9.25
2	16	15	12.0
2.5	20	19	14.25
3	23.5	23	17

The use of the hydrometer is very convenient, because all that is required is to plunge it in the lye cooled to 15° C., and then deduce from the table the alkali which it contains per cubic metre, or per 100 gallons, and thus ascertain its strength.

But conclusions must not be drawn from this which the hydrometer does not show.

The divisions of Baumé's hydrometer are made in such a manner that, plunged in pure water at 15° C., it marks 0° , and when plunged into a solution of salt containing 15 per cent of common salt it marks 15° . The space between 0° and 15° is divided into three equal parts, and these equal divisions are continued above 15° C. It is quite an arbitrary division, and to know the density corresponding to a given degree Baumé resort must be had to another table giving the densities corresponding to the degree Baumé.

COMPARATIVE TABLE OF THE DEGREES OF THE HYDROMETERS OF BAUMÉ, TWADDELL, AND BECK, CORRESPONDING TO THE SAME DENSITY.

Density.	Degrees.			Density.	Degrees.		
	Baumé.	Twaddell.	Beck.		Baumé.	Twaddell.	Beck.
I	0	0	0	1'190	23	38	
1'007	1	1'4		1'199	24	40	29
1'014	2	2'8		1'210	25	42	
1'022	3	4'4			26		
1'029	4	5'8			27		
1'036	5	7'2			28		
1'044	6	8'8		1'250	29	50	34
1'050	7	10	8		30		
1'060	8	12			31		
1'067	9	13'4			32		
1'075	10	15			33		
1'083	11	16'6		1'300	34	60	40
1'091	12	18'2			35		
1'100	13	20	16	1'350	38	70	44
1'108	14	21'6		1'400	41	80	49
1'116	15	23'2		1'450	45	90	53
1'125	16	25		1'500	48	100	57
1'134	17	26'8		1'530	50	106	59
1'143	18	28'6					
1'150	19	30	23				
1'161	20	31'2					
1'171	21	34'2					
1'180	22	36					

When the specific gravity of a lye is taken the experiment

must be made at 15° C. If the hydrometer were plunged in a hot lye the indications would be altogether erroneous.

The British use Twaddell's hydrometer, the Germans Beck's. The above table gives the relations between the densities and the degrees of these different hydrometers. When the Baumé hydrometers are divided from 0° to 40°, for example, the divisions are very small and do not allow of ascertaining accurately enough the strength of a lye. A hydrometer graduated from 0° to 4°, for example, should be used, divided into degrees and tenths of degrees. This hydrometer is only available for lyes the concentration of which does not exceed 4°, but that suffices in practice because stronger lyes are not used.

Proportion between the Weight of Soda and the Weight of the Fabrics.—The specific gravity gives the strength of the lye, that is to say, the energy—greater or less—with which it attacks the soluble portion of textile fabrics, but it is necessary also to proportionate the weight of alkali to the weight of the fabrics. If for a large quantity of fabrics a small quantity of lye be used, it will be exhausted in a short time, and the boiling will not produce the desired effect; if, on the contrary, a large volume of lye be used for a small quantity of fabrics, much alkali will remain in the lye and a useless expense be incurred. The custom is to dissolve in the water the quantity of alkali required for the lye to mark the desired degree Baumé; then a quantity is run into the pan sufficient to completely immerse the fabrics. Weight for weight fabrics occupy different volumes according to their nature; it follows that the volume of lye required to cover the same weight of fabrics is also variable. Experience teaches that 100 kilogrammes of cloth require 600 litres of lye, say 60 gallons of lye per 100 lb. of cloth, and the following table is calculated on that fact:—

TABLE SHOWING THE PERCENTAGE OF ALKALI ON THE WEIGHT OF THE FABRICS ACCORDING TO DENSITY OF LYE.

Degrees Baumé.	Specific Gravity.	Per 100 Kilogrammes or 100 Lb. of Fabrics.	
		Carbonate of Soda or Soda Ash.	Caustic Soda.
		Kilos or Lb.	Kilos or Lb.
0·5	1·0035	2·4	2
1	1·007	4·8	4
1·5	1·0105	7·2	5·6
2	1·014	9·6	7·2
2·5	1·0175	12	8·6
3	1·022	14	10·2

By pressing the fabrics in the pan a larger quantity may be packed into it, and thus the amount of lye may be reduced, but this method of working is not advantageous. This proportion of 600 litres of lye for 100 kilogrammes of fabrics, 60 gallons per 100 lb. of cloth, is a good one and should not be departed from too widely.

Method of Preparing Lyes.—When a lye has to be prepared it is necessary to know the amount of water required to submerge the fabrics and the degree Baumé; from that the quantity of alkali to be used is deduced. For example, if it be desired to make 3000 litres (660 gals.) of carbonate of soda lye marking 2° Baumé, 2·8° Tw. = 1·014 specific gravity, it will be seen, on consulting the table, that it will be necessary to dissolve $3 \times 16 = 48$ kilogrammes of carbonate of soda ($48 \times 2·2 = 105·6$ lb. per 660 gals.). The most convenient method of preparing lye would be to have a tank alongside the keir equal to it in capacity, in which the lye could be prepared of the strength at which it is to be used. It is not always possible to provide such a large tank. If only a small tank be available the necessary quantity of alkali is dissolved in it, so that when once it has reached the keir it may be diluted to the desired degree Baumé. This concentrated solution is pumped into the keir and water run in simultaneously, and then with a pump, or an injector, the whole is circulated so as to thoroughly mix the lye, a sample

of which is taken and tested from time to time until the desired degree Baumé is obtained. The alkali is rather difficult to dissolve; when it is run into the water it aggregates into a mass which is afterwards difficult to dissolve. Solution is facilitated by the use of a cage, the interior of which is lined with wire gauze. This cage is described under the instructions in regard to dissolving lime. It is fixed above the tank in which the alkali is dissolved and is made to partly dip into the water. The alkali is run into the cage and stirred with a rake to dissolve it and to cause it to pass through the meshes of the wire gauze. Its aggregation into masses in the bottom of the tank is thus prevented. When all the alkali is dissolved it is boiled; a quantity of impurities mount to the surface under the form of scum; these are removed with a scraper, and the solution pumped to the keir.

Revivifying the Lye.—When boiling is at an end the lye is run off. When the lye has been used for brown unbleached fabrics, it is highly charged with substances which it has dissolved. The alkali which it contained has been exhausted, there is therefore no object whatever in preserving it. It is not so, however, when the lye comes from the boiling of fabrics which have been previously boiled with lye three or four times; it then still contains a greater or less quantity of alkali which can be utilized in another operation. Instead of running the lye away it should be pumped to a reservoir, and the quantity of alkali added to it which has been used up in the previous boiling. To ascertain the unexpended strength of an old lye, the specific gravity is of no use, as the dissolved substances have increased its density. A lye shows greater density by the hydrometer at the end of a boiling than it did at the commencement. The strength of the old lye has to be tested by the alkalimetric method described in another chapter. It would take up too much time to make these tests after each boiling. They are done on two or three occasions, and an amount of alkali added to the old lye equal to that which was absorbed in the previous boiling process. The density is taken by the hydrometer to see whether the lye has in-

creased in density in proportion to the amount of alkali added.

Temperature of the Lyes.—The solvent property of lyes increases with the temperature. When boiling is conducted with access of air the temperature never exceeds 100° C., but in autoclave keirs the temperature rises with the pressure, and therein lies the advantage which results from boiling under pressure. The following table gives the temperature corresponding to the pressure:—

Temperature of the Steam.	Tension of the Steam.		Pressure in Kilogrammes per Sq. Centimetre.
	In Atmospheres.	In Columns of Water.	
° C.			
100°00	1°00	10°334	1°033
106°33	1°25	12°917	1°292
111°33	1°50	15°501	1°550
116°50	1°75	18°084	1°808
120°64	2°00	20°668	2°067
124°39	2°25	23°251	2°325
127°33	2°50	25°835	2°584
130°98	2°75	28°418	2°842
133°91	3°00	31°002	3°100
136°72	3°25	33°585	3°358
139°29	3°50	36°169	3°617
141°72	3°75	38°752	3°875
144°00	4°00	41°336	4°134

Pressure gauges (manometers) specially intended for lye-boiling pans are made. The gradation is made in kilogrammes and in tenths of kilogrammes, and the corresponding temperature is indicated opposite. With linen and cotton fabrics the temperature does not exceed 120° C. In the examples of treatment the temperature which the author considers most suitable is given for each boiling. When coloured fabrics are being treated temperature plays an important part. Thus, Tailfer observed that a carbonate of soda lye at 1° Baumé, specific gravity 1°007, and heated to 75° C., produces the same effect as a lye at 2° Baumé, 1°014, heated to 60° C. A lye which contains a little caustic soda has a much more energetic effect than a lye containing carbonate of soda alone, and

should not be heated so strongly. There are certain colours—blue, for example—which stand the action of carbonate of soda very badly.

Length of Time Occupied in Boiling.—When, during boiling, samples of the lye are taken from time to time, and the strength tested alkalimetrically, it is seen that the soda goes on decreasing and that at the end of a certain time the diminution in strength stops. It is then time to stop the boiling, as the lye is doing no more work. The results of the tests made by the author are given in the chapter devoted to Mather's keir. The bleacher would derive great profit by repeating them, so as to determine the useful duration of boiling, because the lye works differently according to its degree of concentration, its temperature, the quantity, and the nature of the fabrics. These tests, although simple, are delicate enough to carry out; experience especially determines the time boiling lasts. It is generally stopped as follows: after seven to eight hours for unbleached goods, that is to say, for the boiling with lye preceding the chemick, and three to five hours for white fabrics, that is to say, for the boiling with lye which follows the chemick.

THE DIFFERENT OPERATIONS OF LYE-BOILING.

Stowing the Fabrics in the Keirs.—This is done in several ways. (1) The first consists in arranging the packages upright and pressing them equally. Care must be taken to slacken the cord by which each package is tied. A first tier is made, then a second, and so on. This arrangement is convenient in very wide, shallow keirs. The fabrics are then covered with a sheet, and kept in position by cross pieces or chains, so that the lye may not raise them up. (2) The second manner of charging the keir consists in fixing overhead rollers above the keir which draw the pieces, the end of the one attached to the end of the other, and discharge them into the keir. A workman arranges the folds with a stick, taking care to spread them equally and leave no empty spaces. The pieces are weighted down and the lye run on to them. The shaft of the

delivery rollers carries three pulleys—one fixed and two free. One of the free pulleys carries an upright belt and the other a cross belt; by bringing one or other of these belts on to the fixed pulley the drawing roller may be caused to turn in two different directions, and it thus serves to deliver the pieces into the keir or to draw them out of it. By one or other of these methods the fabrics are deposited in the keir and the lye is then run in. Sometimes the keir is filled with lye and the fabrics deposited therein, either by throwing them in in bundles, or by depositing them in bands or plaits. They are probed down with sticks. This method has one advantage: the fabrics are well impregnated with lye throughout their whole mass. As they are not pressed, there is no reason to fear unequal bleaching or spots from deposits of dirt. The inconvenience of the method is due to the difficulty which is experienced in immersing the fabrics, and to the small quantity which can be got into a keir.

Saturation.—When the pieces can be tacked together end to end it is advisable to pass the lengths through a small tank filled with lye, from which the rollers draw them into the keir. This operation is called saturation, and its object is to impregnate the fabrics with lye; it is easier to lay them in the keir and no imprisoned air is left in the folds. Instead of a small tank through which the lengths pass only once, a washing machine is made use of, the trough of which contains the lye. The lengths making three or four revolutions through the lye are more thoroughly saturated, and this saturation is rendered more perfect by the compression of the rolls. In the case of those keirs where two lengths are deposited simultaneously, the washing machine is also arranged to saturate two lengths at the same time. The lengths run in at the two ends of the rolls and come out in the centre. This arrangement is described under Mather's keir.

Washing in the Keir after Lye-Boil.—When the boiling is at an end, and the spent lye run off, it is advisable to give the fabrics a preliminary washing in the keir. The discharge tap is closed, hot water is turned on until the keir is full, and

then it is run off; then cold water is turned on and allowed to run away until it issues clear and colourless from the draw-off cock. Instead of only running the water once through the fabrics, it is caused to circulate by the steam injector or the pump, and then it is run off through the discharge pipe. The same operation is repeated two or three times. Acting in this way a better result is obtained, only care must be taken not to stir up the dirt which has accumulated in the bottom of the keir and spread it over the fabrics. When the fabrics are boiled with caustic lye the washing in the keir is not enough. If the next operation be exposure on the green, they must receive a further washing by machine. But if the lye be a carbonate of soda lye, and the fabrics fine and permeable, the bleacher may be content with washing in the keir before sending the fabrics to the chemick, or to exposure on the bleaching green.

Description of Keirs Used in Lye-Boiling. 1. *Keir in which the Lye is Heated with Naked Fire.*—Formerly, before vessels heated by steam became general, the lye was heated by making a fire under the keir, and a hollow column placed at the side or in the centre, the puffer pipe, allowed the lye brought up by the pressure of the steam to fall back on the top of the fabrics, and a continual circulation of the lye was kept up in this manner. When the keirs were of wood the lye was heated in a cast-iron vessel built over a furnace; the lye ran from the keir into the boiler, from which it was taken back with a lye pot, to be again poured into the top of the keir containing the fabrics. This is the method still used in the country to wash household linen. The lye is extracted from wood ashes, the water dissolving the carbonate of potash which they contain; the ashes are put into the bottom of the vessel with twigs of trees or pebbles to prevent them settling at the bottom and stopping the circulation, a sheet of gauze preventing the mud from mingling with the lye.

2. *Wooden Keir Heated by Steam, with Circulation of the Lye.*—Wooden keirs are still used in many bleach works. They are made of pine, the staves are supported by iron

hoops, the pipe in which the lye circulates is placed either outside or inside, and the circulation is produced by an injector which heats the lye at the same time. These keirs keep the heat well, especially if they are furnished with a wooden lid. The temperature does not exceed 90° C. (194° F.), because the circulation is bound to be intermittent; in fact, if the steam is allowed to pass continually through the injector, it comes to pass that steam alone issues from the circulation pipe, and does not bring up the lye when its temperature is too high. Steam must then be shut off, and the whole allowed to cool before turning it on to cause the lye to circulate again. It is well to have near the keir a tank for saturating the fabrics with lye, and a tank for making the lye itself. The false bottom of the keir is of wooden laths nailed to grooved cross pieces so that the lye may be drawn from all parts of the false bottom. The heads of the nails should be well driven home, and care must be taken that they do not pass right through, because they would tear the fabrics. Wooden pegs may replace the nails with advantage. In lieu of a false bottom, the bottom of the keir is lined with a layer of pebbles or prunings of trees.

3. *Cast or Wrought-Iron Keirs.*—Wooden keirs have been replaced by cast or wrought-iron keirs. These keirs generally have lids, and are substantial enough to resist a pressure of two to three atmospheres. The working pressure should not exceed one and a half atmosphere. This plan affords two advantages. The keir being closed, there is less loss of heat; by increasing the pressure the temperature of the lye is elevated, and its action becomes more energetic. In Fig. 18 there is given an illustration of a cast-iron keir with lid. Cast-iron keirs are heavier and dearer than wrought-iron keirs, but they last longer and resist the attacks of rust better. When the fabrics to be boiled are very fine the interior sides of the keir are lined with wooden staves. By coating the outside of the keir with a non-conductive boiler composition the loss of heat is further diminished. The column in which the lye circulates, at the bottom of which is the injector, may be fixed

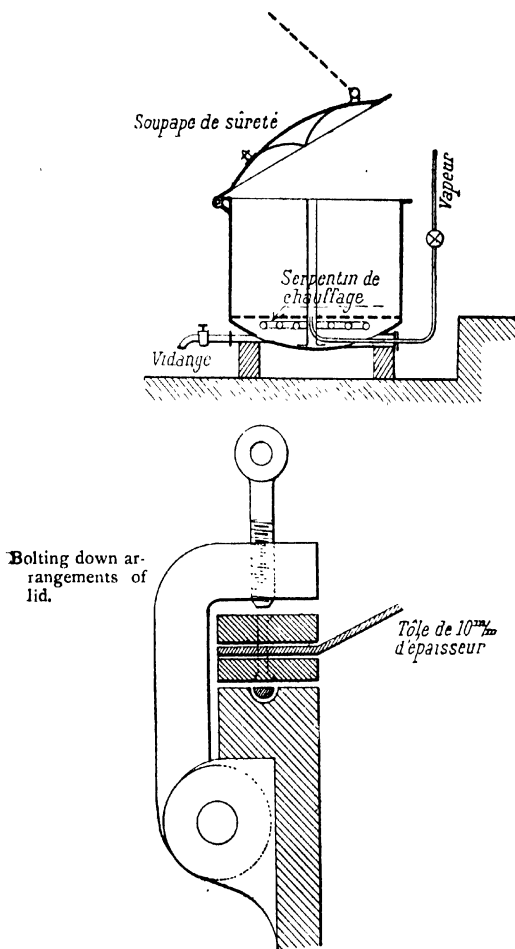


FIG. 18.—Cast-iron keir.

Explanation :—

Soupape de sûreté = Safety Valve.*Vapeur* = Steam.*Vidange* = Discharge Pipe.*Serpentin de chauffage* = Steam Coil.*Tôle de 10 mm. d'épaisseur* = $\frac{3}{8}$ inch Iron Plate.

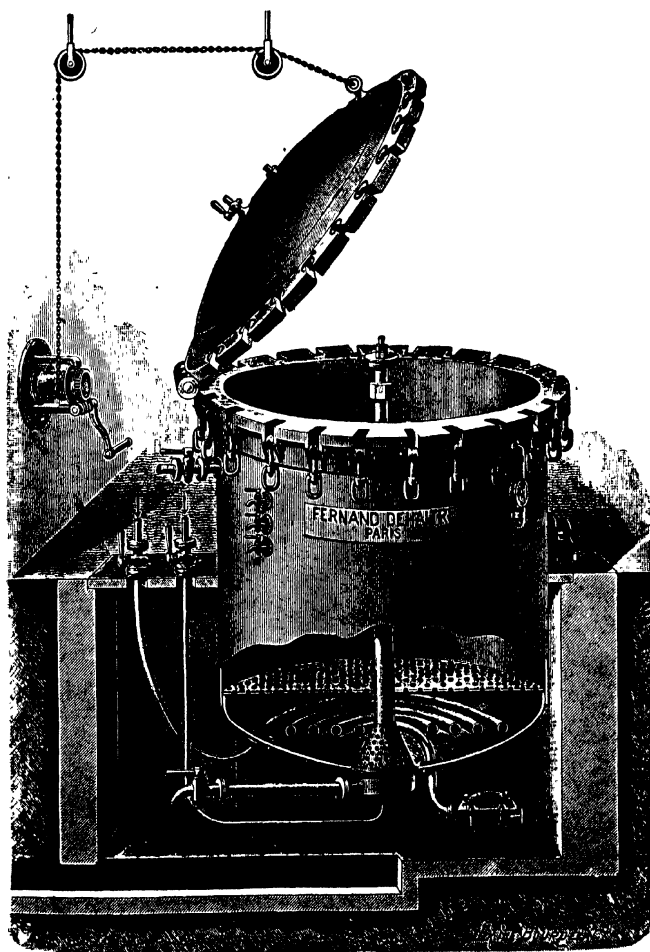


FIG. 19.—Pressure keir fitted with perforated false bottom. Heated by steam coil, perforated steam cone, and lye distributed over fabrics by puffer pipe.

either on the side or in the centre. It is preferable to fix it in the centre, because the lye spreads and distributes itself more regularly on all sides; but this arrangement is sometimes rather awkward for the stacking of the fabrics in the keir. The lid is made of wrought iron, the flanges rest between two circular bands of cast iron which impart rigidity to it, and through which pass the screws with which it is bolted down. The lid is lifted up and let down by a chain and windlass. The lid is kept up by a wooden block so as to prevent accidents by the snapping of the chain. When the lid is on, it is fixed by iron clamps and screws which bear upon the iron bands. There is a small channel on the flange of the keir, in which a layer of hemp is placed so as to make a tight joint. The space between the clamps is about 0.50 metre (say 20 inches) from axis to axis. These keirs are generally very wide (2 to 3 metres in diameter, say $6\frac{1}{2}$ to $9\frac{3}{4}$ feet) and shallow (1.50 to 2 metres, say 5 to $6\frac{1}{2}$ feet). They are badly adapted to stand pressure. They must therefore be made of very thick cast or wrought iron; on the other hand, they are handy for stacking the fabrics, especially when in bundles. The lid requires a large, free space for opening; the rollers, therefore, which deliver the fabrics into the keir and withdraw them ought to be fixed very high up. The fabrics are kept pressed down by iron bars which fit into notches cast on the pan when being made. If the pan be of wrought iron, pieces of angle iron are fixed to it, the flanges of which keep the bars in position. A pan 2.60 metres in diameter (say $8\frac{1}{2}$ feet) by 1.60 metre ($5\frac{1}{4}$ feet) in depth may hold from 1.5 to 1.8 metric tons (say 3375 to 4000 lb.) of fabrics, leaving on the top the necessary space for swelling up with the steam (say 12 inches). The space occupied by the fabrics is from .6 to 7 cubic metres (say 210 to 250 cubic feet) or about 300 kilogrammes (say 660 lb.) of fabrics per cubic metre of 35.3 cubic feet.

4. *Pressure Keir with Circulation of the Lye by a Centrifugal Pump.*—In order to secure quick circulation of the lye, pumps are resorted to. Centrifugal pumps are best adapted

for this purpose. The circulation is thus independent of the steam supply, which is regulated so as to obtain a suitable temperature, say 60° to 80° C., for the boiling of certain fabrics

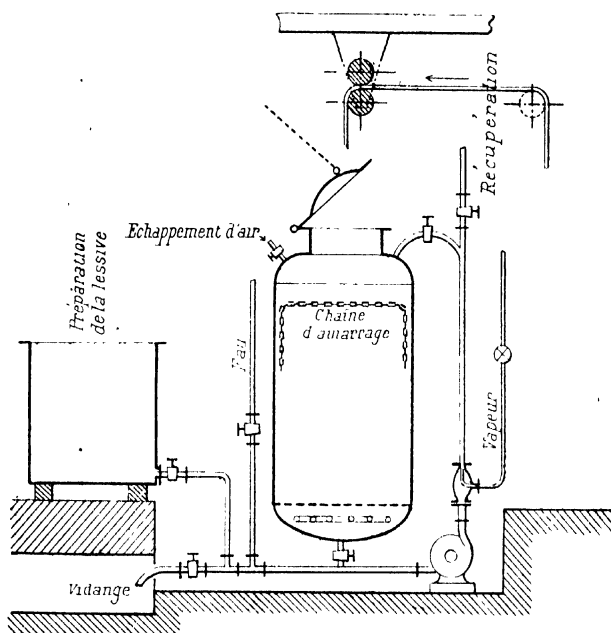


FIG. 20.—Pressure keir.

Explanation :—

Préparation de la lessive = Lye Preparation Tank.

Echappement d'air = Air Valve.

Chaine d'amarrage = Weighting-down Chain.

Eau = Water.

Vapeur = Steam.

Vidange = Discharge Tap.

which require to be washed at low temperatures, or 100° to 120° C. for boiling at high pressure in pressure keirs. This cannot be done in keirs where the circulation is effected by a steam injector fixed in the column which elevates the lye. If it be desired not to exceed a certain temperature, the steam

must be turned off and consequently the circulation interrupted. If, on the other hand, a high temperature be required more steam is turned on, but by-and-by the lye, becoming too hot, ceases to rise, and steam alone issues from the circulation column. The circulation stops also in closed keirs when there is not enough difference between the pressure of the steam in the steam supply pipes and in the interior of the keir. This system is still much employed because it requires no motive power, as in the case of a pump. Nevertheless the advantage of effecting the circulation of the lye by a pump has been so far recognized that its adoption is becoming more and more general. Circulation can be effected by a pump, no matter what system of keir be used. The following very suitable arrangements give very good results (see Fig. 20): The keir consists of a vertical wrought-iron cylinder, the top of which is closed by a lid, worked by a chain and windlass. The lid is fastened by clamps tightened with screws, or by any other means strong enough to resist pressure. The depth of the keir is about $1\frac{1}{2}$ times its diameter. This ensures a better circulation of the lye throughout the whole of the pan. If the diameter of the keir be very great in proportion to the depth it is difficult for the lye to spread all over its surface, and it is to be feared that circulation is only effected in certain parts and not in all. A keir, the cylindrical portion of which is 3.30 metres (say 11 feet) in depth and 2.25 (say 7 feet) in diameter, may contain 2000 kilogrammes (4500 lb.) of fabrics. The pieces are delivered into the keir by a pair of rollers or cotton winders, fixed above the centre. The fabrics are kept down by wooden cross pieces, supported by wooden uprights. Chains also answer very well for this purpose. It is advisable not to press the fabrics too tight, but to leave them room to rise a little after the lye has been introduced; acting in this way the lye penetrates better and spots are avoided. This last observation, which has been verified by the author, was communicated to him by an English foreman. The keir is furnished with a gauge glass to show the level of the lye, safety valve, mano-

meter, pressure gauge, and steam blow-off cock. The pump ought to be placed as low as possible so as to work by propulsion and not by respiration. It takes the lye from the bottom of the keir and propels it to the upper part, and thus keeps the lye in constant circulation during the whole of the boiling process. The output of the pump should be such that the whole of the lye should be withdrawn and propelled in the space of twenty to thirty minutes. For example, if there be 4000 litres (say 900 gals.) of lye to displace, the output of the pump should be $\frac{4000}{20} = 200$ litres (say 45 gals.) per minute, or $\frac{4000}{30} = 133$ litres (or 30 gals.) per minute. The heat is supplied by a steam pipe fixed below the false bottom. It is still advantageous to lead the steam into the interior of the lye ascension column, the pipe being in the form of an injector. The steam heats the lye, and at the same time helps to circulate it. The lye is made in a tank communicating with the keir by means of a pipe. It is well to have this tank of the same capacity as the keir, so that the lye may be prepared of the exact strength at which it is to be used. The lye is pumped from the tank into the pan containing the fabrics. If it be not desired to have such a large tank, the strong solution of soda is made in a small tank, and this solution is run into the keir simultaneously with water to dilute it. The whole is mixed by the pump, and the strength verified by a hydrometer. Care must be taken before pumping the lye on to the fabrics to boil it in the tank in which it has been made, and to skim off all the impurities which float to the top in the form of scum. When the boiling is finished the lye is run off. If the soda be not all spent, it is economical to pump it into a revivifying reservoir and to use it in another boiling, after having been revivified. The *washing* in the keir may be done with either hot or cold water. The water may be heated in the tank in which the lye was prepared. It is run into the pan, circulated by the pump, and then run off. Washing with cold water may be done in the same way.

Sir James Farmer's (Manchester) Keir.—This keir, represented in Fig. 21, has certain features which render its use,

advantageous. It is distinguished by its indicator and automatic circulation governor.

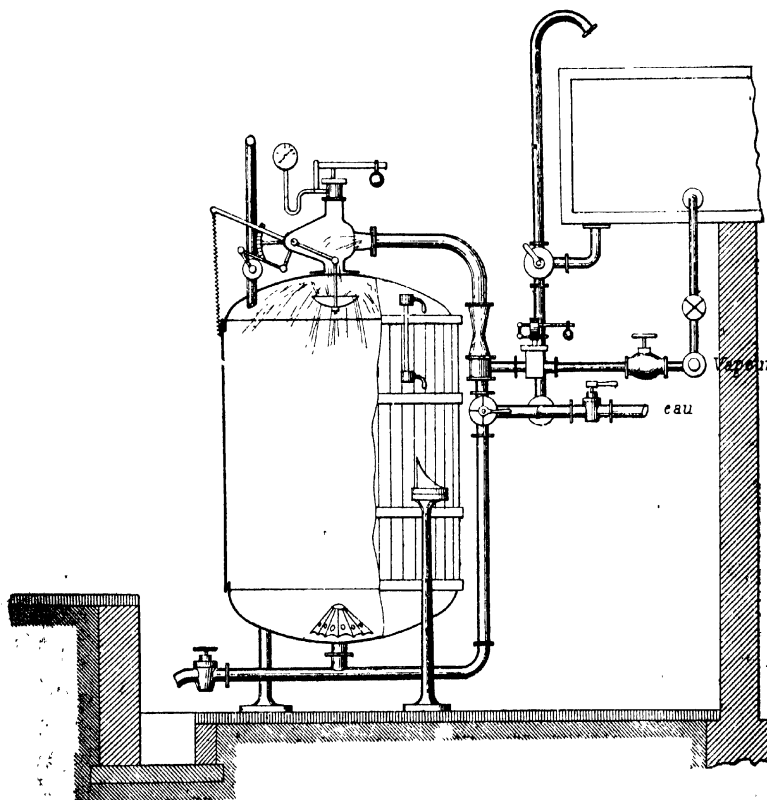


FIG. 21.—Farmer and Spende's keir, with indicator and automatic circulation regulator.

Explanation :—

Vapeur = Steam.

Eau = Water.

Pressure.—The keir is constructed to work at high and low pressure; it is tested to work at a pressure of 2 kilogrammes per square centimetre (say a temperature of 120° C.

and a pressure of 2 atmospheres). The fabrics are delivered into the pan in the usual way, and pass through two manholes, which allow of two lengths of cloth being introduced at the same time. These manholes are closed by hinged lids and screw bolts, so that no time need be lost in opening or shutting them. The keir can be used equally well for boiling with lime, salt of soda, or caustic soda, and is easily worked by a simple bleach works hand.

Injector.—The liquid is put in circulation by means of a special form of injector, which does away with the use of a pump, and is constructed in such a way as to spend as little steam as possible.

Reducing Valve.—It is advantageous to provide the keir with a reducing valve, which is fixed near to the injector. This facilitates considerably the watching of the progress of operations by the bleacher.

Farmer's Governor and Indicator.—The circulation is controlled by Farmer's automatic governor and indicator, which shows at each moment the force of the circulation, and prevents all stoppages due to equilibrium of pressure in the keir. The indicator-governor consists of a plate pierced with holes, and in form of a bonnet (*grid bonnet*), which is hung on a rod at the end of a lever; this lever moves an arm which issues from the exterior of the triangular box represented by the top of the keir. A stuffing box prevents the escape of steam. A lever is pivoted on this axis outside the box, and connects with a spring. According to the pressure of the steam the plate stretches the spring more or less, and the exterior lever moves the length of a segment and shows at each moment the force of the circulation. Another small lever, pivoted on this same axis, is fixed by an articulated system to the key of an air valve. When the pan is ready to start work the air valve is connected by these levers to the governor. So long as the circulation is normal the air valve remains closed; but as soon as it slackens, the spring raises up the movable plate, and partially opens the air valve. The difference of pressure between the steam in the keir and that in the gener-

ator is re-established, and the circulation resumes its normal force. The bleacher's attention is fixed on the working of his keir during the whole period of boiling, and he controls it by watching the oscillations of the lever.

Introduction of the Steam.—The fabrics may be heated to the boiling-point by dry steam before running in the lye. In this way it is not reduced to any appreciable extent during the boiling. This reduction may be still further reduced by covering the outside of the keir with wooden boards which diminish the cooling surface, and consequently the condensation of steam in the lye.

Valves and Pipes.—All the valves and taps are easy of access. The three-way taps are provided with a copper dial indicating the directions. The arrangement of the piping is such that numerous operations may be conducted. A three-way tap placed below the injector allows of the following being put in communication :—

(a) The bottom of the keir with the circulation injector. (b) The lye-reservoir with the keir. (c) The bottom of the keir with an overhead pipe, to convey the lye into a reservoir if required. (d) The cold-water cistern with the injector, to wash with cold water or to cool the keir.

Hood.—The hood, placed at the bottom of the keir, is conical in shape, with an undulatory surface to prevent the fabrics from obstructing the holes. Some bleachers line the bottom of the vat with twigs. The hood is admirably adapted for this purpose.

Gauge Glass.—This, instead of being placed on the steam or circulation pipe, as is customary with high-pressure keirs, is fixed directly on the body of the pan, where it enables the quantity of liquid to be controlled from the beginning to the end of the operation.

Method of Working the Keir. 1. *Filling.*—The fabrics are introduced through the two manholes, two strands being delivered simultaneously; then the manholes are closed.

2. *Steaming.*—The steam valve is opened as well as the air escape and the discharge tap. When the air valve com-

mences to let out steam it is closed and the steam kept on until the keir becomes hot and the steam is seen to escape by the tap at the bottom of the keir. When the fabrics have been saturated with caustic soda it is advantageous to collect the water condensed during the steaming operation. In that case the discharge tap is closed and the bottom of the keir is brought into communication with the pipe leading to the overhead reservoir and the condensed liquid pumped up into it.

3. *Running the Lye into the Pan.*—The discharge pipe is closed, and the steam turned off immediately afterwards. The air valve is opened and the lye is then introduced into the keir, either by its own weight, by running through the three-way cock and entering the pan from below, or it may be propelled by the injector and spread over the top of the fabrics. Enough lye ought to be run into the keir to partially float the fabrics.

4. *Circulation.*—The lye having been run in to the pan, circulation is started by putting the bottom pipes in communication with the injector through the three-way stop-cock and turning on steam at full pressure. The air blow-off cock is then connected with the governor, and the boiling proceeds without any further attention.

5. *Washing.*—After the fabrics have been sufficiently boiled, the steam is stopped, and the lye run off or pumped to the overhead reservoir to be again used. If the fabrics are to be washed in the keir hot water from an overhead reservoir is run in, circulated a few times, and cooled.

6. *Cooling.*—In order to cool the keir, the bottom tap is opened, and cold water is run over the fabrics by means of the injector. A partial washing with cold water is thus effected. The fabrics are then taken out of the keir to receive further treatment.

Advantages of Farmer and Spindel's Keir.—(1) The arrangement of the keir is adapted to the great number of processes in use by bleachers—boiling with lime, rosinate of soda, pure caustic soda, etc. (2) It is simple and cheap, and the

process may be advantageously applied to every description of high-pressure keir at present in existence. (3) Circulation is absolutely certain, and the time required for boiling is reduced to a minimum. (4) Washing operations may be effected in this keir as perfectly as in any other.

CHAPTER X.

SPECIAL METHODS OF LYE-BOILING—MATHER'S KEIR (OLD MODEL).

Mather and Platt's Keir.

SOME twenty-five years ago Mather and Platt of Manchester put on the market a keir by the use of which important advantages are obtained. How time, chemicals, and fuel may be economized by the use of this keir is evident from the description of the principle on which it works as well as the treatment to which the fabrics are subjected. There are two models, the old and the new. We shall describe the old model first.

Description of the Keir (Old Model).—The keir consists of a wrought-iron cylinder placed horizontally. At one extremity is a door which is manipulated by a hydraulic piston. Inside the keir rails are laid in communication with huge rails which connect with outside rails, and it is on these rails that the wagons filled with fabrics or other materials that are to be bleached circulate in and out. These wagons are made of galvanized sheet-iron and are provided with a perforated false bottom. The circulation of the lye is effected by a centrifugal force pump. The re-issue pipe is divided into two branches so as to spread the lye evenly over each wagon. At the point where it is spread over the wagons, a cast-iron plate breaks up the current and causes it to spread itself in the form of rain. The bottom of the wagons is put in communication with a collecting conduit through which the lye returns to the pump. On the side of the pipes which spread the lye over the wagons glass indicators are fixed, so that the man in charge may be

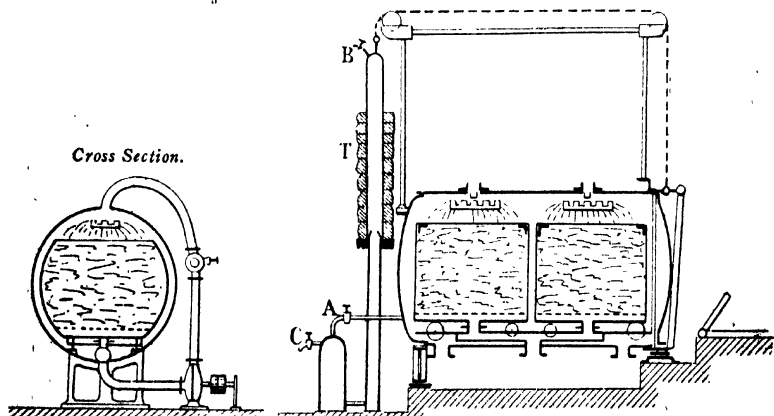
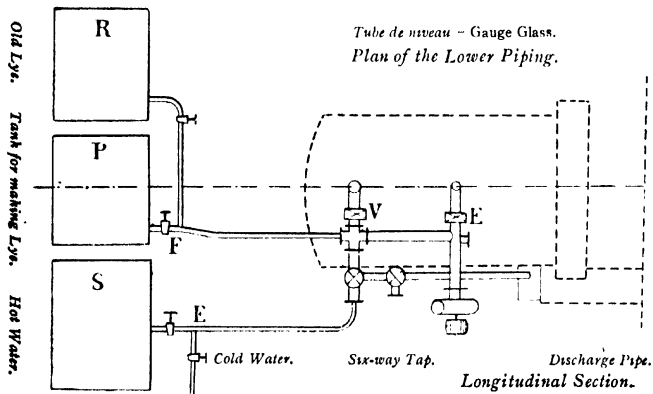
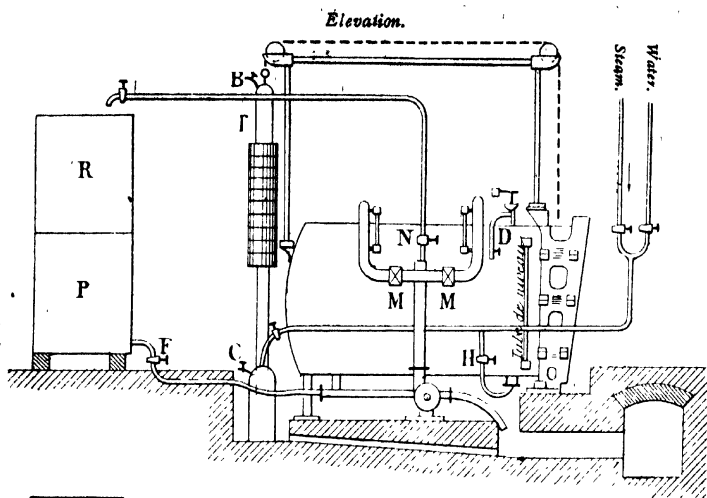


FIG. 22.—Mather's keir.

able to see whether the circulation is going on all right or not. A level tube or gauge glass shows the height of the lye inside the tube. The lye is heated by a closed steam coil placed in the bottom of the keir. The condensed water from the steam runs away on the outside so as not to dilute the lye. The lye may be and most generally is heated with direct steam by means of a perforated steam coil, the steam heat being thus more fully and beneficially utilized. The wagons are taken out of the keir by a winch chain and pulleys suitably fixed by which the wagons may also be transferred to any desired place. Turntables are placed at the intersection of the line of rails. The door is wedge-shaped and fits into a frame with inclined sides or edges. In this manner the door is wedged in when it is brought down to the shutting position, and it is kept, in that position by a cam worked by a lever. The door is balanced by a weighted cylinder to which it is attached by a chain passing over pulleys. The cylinder slides on a hydraulic piston the bottom of which communicates with the lower part of a pressure reservoir. To close the door, steam is introduced into the upper part of this reservoir, and the steam presses on the water; this pressure is transmitted by the water to the hollow mobile cylinder; it rises and the door descends by its own weight.

Accessories.—The accessory plant required for Mather's keir consists of:—

A tank or cistern for preparing the lye, P.

A revivifying reservoir, R, for the old unexhausted lyes which can be used over again.

A hot-water reservoir, S, for washing in the keir.

A small cast-iron tank for the concentrated soda lye of 33° to 35° Baumé.

Principles on which the Keir Works (see Fig. 22).—The wagons charged with fabrics having been run into the keir, the door is closed.

Method of Closing the Door.—Open the tap B (Fig. 22, Elevation, and Fig. 22, Longitudinal section) to let out the air, let the water run in by the tap A (Fig. 22, Longitudinal

section) until it is seen to issue from the tap B (Fig. 22, Elevation and Longitudinal section). Close this latter tap, then introduce steam through the tap A. The pressure of the steam causes the cylinder T (Fig. 22, Elevation and Longitudinal section) to rise up, and the door then descends by its own weight, and is wedged up by the eccentric wheel. This done, the steam and water are allowed to escape by the gauge tap C (Fig. 22, Elevation and Longitudinal section).

Boiling.—In order to start boiling leave the tap D (Fig. 22, Elevation) open for the air to escape. Close the tap E (Fig. 22, Plan of Lower Piping). Open the tap F (Fig. 22, Elevation and Plan) of the lye preparation tank. Set the pump to work. The lye falls on the top of the wagons. When all the lye has been pumped in, say about 4000 litres per 2000 kilogrammes of fabrics (say 400 gals. per 2000 lb.), the tap F is closed and the tap E opened so as to start the circulation. Steam is introduced by the tap H (Fig. 22, Elevation) leaving the tap D open for the escape of the air chased out and replaced by the steam. Steam is led on when the coil in the bottom of the keir is replaced by lye; only a small jet of steam is put on to keep up the temperature of the lye, which is cooled by contact with the fabrics. When all the lye has been pumped into the keir the steam is laid full on, and the process goes on in this way (always keeping up communication with the atmosphere) for an hour if the fabrics have been saturated with lye before being piled in the wagons, and for two hours if they have not been so saturated. Then the tap D is closed, and the pressure is raised to correspond with the temperature which it is desired to impart to the lye. As soon as this pressure is obtained the steam is so regulated as to maintain the pressure during the boiling, which lasts from four to eight hours. At the end of that time the lye is run off by opening the exit tap V (Fig. 22, Plan of Lower Piping). The pump is kept at work during the time the lye is being run off. The steam tap is shut off after the lye is run off, so that the pressure may fall. If the lye is to be revived, the taps M (Fig. 22, Elevation) are

closed and the taps N (Fig. 22, Elevation) opened, and the lye pumped into the revivifying tank.

Washing in the Keir.—For the purpose of washing, the hot-water reservoir is put in communication with the pump. About 4000 litres of water are run in for the typical example of 2 tons of fabrics. Circulation is kept up for one half hour, and the wash water then run off. Four thousand litres of fresh water are then run in, circulated for half an hour, and run off as before. If cold water be run in, it must be heated in the keir by steam, because cold water does not wash the fabrics well. When the washing is finished, the door is opened and the wagons run out.

Method of Opening the Door.—In order to raise it gently, open the tap B to allow the air to escape; run in water through the tap A until it runs out through the tap B (the water should be run in under pressure so as to fill the piston T); close the taps B and A, unwedge the eccentric of the door and open the purging cock C. As the cylinder T is heavier than the door it falls, causing the door to ascend and pressing the water through the tap C, which regulates the speed at which the door is raised. The wagons as they come from the keirs are brought in front of the roller washing machines which draw the fabrics from the wagons and wash them. When treating hanks of linen or cotton yarn, ribbons, quilts, etc., the fabrics are taken from the wagons by hand and washed in special machines. If the fabrics are to be chemicked after lye-boiling without being spread out on the bleaching green, the washing in the keir suffices; should any soda remain it will only render the action of the chemick a little slower.

Lye-Boiling with Mather Keir.—The chief advantage of the Mather keir consists in its allowing of the lye-boiling of fabrics without risk with soda absolutely caustic. This soda has a much more energetic action than salts of soda (a mixture of carbonated and caustic alkali). A more pronounced white is thus obtained with fewer operations. But to work safely with caustic soda it is necessary at all hazards to prevent the air being imprisoned within the fabrics during the boiling. A

good precaution is to impregnate the fabrics with caustic before piling them on the wagons. It is also necessary to expel the air from the keir before putting on the pressure for boiling at a high temperature. This is done by opening a tap communicating with the outside air until the steam expels the air from the interior of the vat and takes its place. This tap is then closed and the pressure raised so as to obtain a higher temperature. Finally, when the boiling is finished the fabrics must be well washed, either inside the keir, or after having withdrawn them from the wagons. Either operation is an excellent precaution. The fabrics are thus prevented from drying in contact with the air whilst impregnated with caustic soda, which would be very prejudicial to them.

The author insists specially on this point because he has seen fabrics burnt by caustic soda under circumstances such that he has been able to attribute it solely to the action of the air imprisoned in the fabrics. On taking precautions to prevent this the fabrics remained perfectly sound.

Before chemicking it is very advantageous to boil the fabrics in a soda lye purely caustic, and, further, if this be not done one of the great advantages of the Mather keir is lost.

Carbonate of soda, without any addition of caustic, is usually preferred for the lye-boilings after the chemick.

The use of salt of soda is not very judicious, and that for two reasons: in the first place, when caustic soda injures the fabrics it must not be used at all, and carbonate of soda alone is used: in the second place, where caustic soda is attended with no risk, then it is preferable to use it pure, and of a suitable strength so as not to damage the fabrics. For example, it would be preferable to replace a salt of soda lye of 2° Baumé by a caustic soda lye of 0·5° to 0·8° Baumé. Greater economy and a more beautiful white are obtained.

Saturation of the Fabrics.—The object of this operation is to impregnate the fabrics with lye before piling them in the wagons. If hanks of yarn, or linen or cotton ribbons are to be treated they are first plunged into a lye of salt of soda, or of caustic soda; they are then arranged in the wagons, packing

them regularly in such a manner that during the boiling the lye circulates throughout the whole mass and does not simply pass through the less lightly packed portion leaving the other parts untouched.

Saturating Roller Washing Machines. For Saturating Fabrics with Lye before Lye-Boiling.—This plan of saturating is for use in connection with Mather's keir where the fabrics are delivered into wagons which are run into the keirs, but the method is identical with that used when the cloth is laid direct into the keir itself. When the fabrics can be tacked on to each

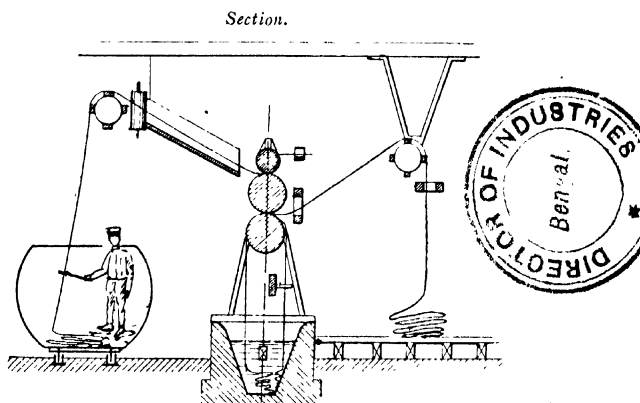


FIG. 23.—Roller alkali saturating machine.

other, end to end, a roller washing machine is used, into the beck of which the lye is run. A single roller machine can fill two wagons simultaneously. The fabrics are delivered into the wagons which brought them, or on to a wooden board where they have been deposited. The rolling machine delivers two lengths at the same time; "pot eyes" guide their entrance; they issue forth in the centre. Reels deliver a strand in each wagon, where they are packed by a boy by aid of a stick. The lengths are guided between the rolling washing machine and the delivery reels by wooden gutters or shoots, down which the lye runs back into the beck of the roller washing machine. Each length makes three circulations through

the machine, and the squeezing it undergoes between the rollers causes the lye to penetrate into the interior of the

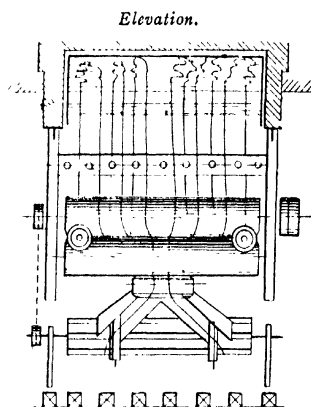


FIG. 24.—Roller alkali saturating machine.

fabric. The linear speed of the length is about 5000 metres (say 3 miles) an hour. Working with two pieces, and taking

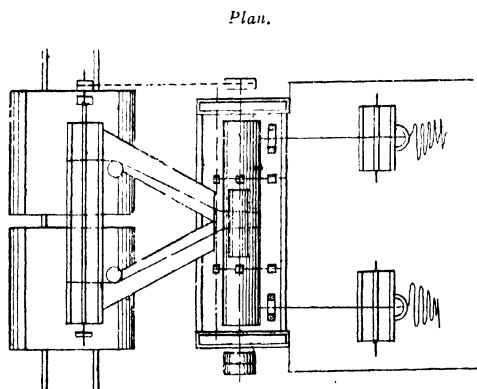


FIG. 25.—Roller alkali saturating machine.

different stoppages into account, the two wagons may be filled with 500 pieces of cambric of an average length of 18 metres

(say 59 feet) and of a total weight of about 2200 kilogrammes (say 2 tons) in two hours.

Saturating Beck.—A simpler method is to have a saturating beck filled with lye, through which the fabrics pass, and two winding rollers deliver them into the wagons. The lye runs back into the beck down a wooden shoot. This plan is cheaper and occupies less room than the former, but saturation is not so well effected.

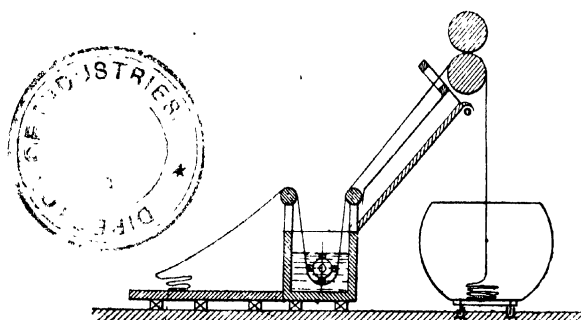


FIG. 26.—Alkali saturating tank with rolls for saturating cloths before piling into wagons.

The following is the analysis of the caustic soda used by Tailfer in his experiments in lye-boiling with the Mather keir (old model):—

	Per Cent.
Caustic Soda, NaHO - - - - -	89
Impurities - - - - -	11
	<hr/> 100

The mixture of caustic and carbonated alkali of 80 Descroizilles, say 50 per cent Na_2O , contained:—

	Per Cent.
Caustic Soda, NaHO - - - - -	20
Carbonate of Soda, Na_2CO_3 - - - - -	59
Impurities - - - - -	21
	<hr/> 100

The carbonate of soda was Solvay soda ash, say 58 per cent alkali, and contained:—

Carbonate of Soda	-	-	-	-	-	Per Cent.
Impurities	-	-	-	-	-	99.0
						1.0
						<u>100.0</u>

The following table gives the weight of these different salts which it is necessary to dissolve in 100 gallons of water so as to get the corresponding degree Baumé. This degree varies according to the composition of each sample of alkali and the impurities which it contains. For each alkaline substance of different composition this correspondence must be determined. Practically, the table is sufficiently exact. The weight of alkali to dissolve to obtain the tenths of degrees between the intervals can be calculated by proportion.

Degrees Baumé.	Specific Gravity.	Lb. per 100 Gallons of Water.		
		Carbonate of Soda.	Salt of Soda.	Caustic Soda.
		Lb.	Lb.	Lb.
0	0	0	0	0
0.5	1.0035	4	4	3.25
1	1.009	8	8	6.75
1.5	1.0105	12	11.5	9.25
2	1.014	16	15	12
2.5	1.0175	20	19	14.25
3	1.022	23.5	23	17

Mather Keir (Old Model). Quantity of Alkali in Proportion to Weight of Fabrics.—This point has also to be considered. In fact, if the lye, being of suitable strength, be too small in quantity, it will be quickly exhausted, and the latter part of the boiling process will produce no effect. If too much be employed a useless and exaggerated expense for chemicals is incurred. In the examples of different processes about to be given it is presumed that the keir has such a capacity that 2000 kilogrammes of fabrics may be treated at a single operation. For that quantity 2500 litres of lye will be required for saturation and 3500 litres for boiling, say a total of 6000 litres. Under these conditions the three following columns give the percentage of chemicals in proportion to the weight

of the fabrics, corresponding to the degree Baumé at which the lye has been prepared :—

Carbonate of Soda.			Soda Ash (Caustic).		Caustic Soda.	
Degrees Baumé.	Specific Gravity.	Per cent on Weight of Fabrics.	Degrees Baumé.	Per cent on Weight of Fabrics.	Degrees Baumé.	Per cent on Weight of Fabrics.
0	0	0	0	0	0	0
0·5	1·0035	1·2	0·5	1·2	0·5	1
1	1·007	2·4	1	2·4	1	2
1·5	1·0105	3·6	1·5	3·5	1·5	2·8
2	1·014	4·8	2	4·5	2	3·6
2·5	1·0175	6	2·5	5·7	2·5	4·3
3	1·022	6·8	3	6·32	3	5·1

For example, for a carbonate of soda lye of 2° Baumé it requires 16 kilogrammes of carbonate of soda per 1000 litres (say 16 lb. per 100 gals.). Therefore, for 6000 litres it will require $6000 \times 16 = 96$ kilogrammes (say 96 lb. per 600 gals.), and as that quantity will lye-boil 2000 kilogrammes (2 metric tons) of fabrics the percentage will be $\frac{96}{200} = 4·8$.

Soap. Mather Keir (Old Model).—For the lye-boils before the chemick rosin soap is generally employed, because it costs less, and because at a high temperature the rosinsates of soda have special solvent properties. It is not prudent to use rosin soap for the boilings which follow the chemick, as there is then the risk of spots from unsaponified rosin. Olein soap or white soap should be used. When the fabrics have passed through the soap-rubbing machines it is useless to add soap to the saturation lye, as the fabrics are already impregnated with it. In other cases it is put in the two lyes. The quantity of soap to use is 1 to $1\frac{1}{2}$ kilogramme per 1000 litres of lye (say 1 to $1\frac{1}{2}$ lb. per 100 gals.).

Duration of the Lye-Boiling.—Matters must be so arranged that the lye-boil does not exceed ten hours so that two batches may be treated in twenty-four hours, and time allowed for the entrance and exit of the wagons and the getting ready of the

keir. The following course may be adopted which represents the maximum length of time occupied in the process :—

	Hours.
Boiling at the atmospheric pressure - - -	1
In getting up pressure - - -	$\frac{1}{2}$
Boiling under pressure - - -	6
Running off or recovering the lye - - -	$\frac{1}{2}$
First washing in the keir - - -	1
Second washing in the keir - - -	1
	<hr/> 10 <hr/>

The nearer the fabrics approach white the shorter should be the lye-boil. The useful duration of each boiling has been determined by the following experiments.

The undernoted experiments show how the lye acts and have enabled the following conclusions to be drawn therefrom.

1. Unbleached raw cambrics, first caustic soda lye-boil, at 2·8 per cent on weight of fabrics.

Boiling at 118° C.	Degrees Baumé.	Alkalinity.
Fresh lye - - -	1·5	1·15
After 2 hours - - -	1·6	0·78
After 5 hours - - -	1·7	0·30
After 6 hours - - -	1·8	0·20

2. Cambrics second lye-boil with caustic soda, at 2·8 per cent on weight of fabrics.

Boiling at 118° C.	Degrees Baumé.	Alkalinity.
Fresh lye - - -	1·5	1·15
After 2 hours - - -	1·6	0·90
After 4 hours - - -	1·6	0·75
After 6 hours - - -	1·7	0·60
After 7 hours - - -	1·8	0·60

3. Cambrics, lye-boil after the first chemick with carbonate of soda, at 4·5 per cent on weight of fabrics.

EXHAUSTION OF LYE IN LYE-BOILING—MATHER'S KEIR. 133

Boiling at 105° C.	Degrees Baumé.	Alkalinity.
Fresh lye - - -	1·8	1·30
After 2 hours - - -	1·7	1·10
After 4 hours - - -	1·7	0·85
After 6 hours - - -	1·7	0·84
After 7 hours - - -	1·7	0·84

4. Cambrics, lye-boil after the second chemick, with 3 per cent of carbonate of soda on weight of fabrics.

Boiling at 105° C.	Degrees Baumé.	Alkalinity.
Fresh lye - - -	1·2	0·88
After 1 hour - - -	1·2	0·85
After 2 hours - - -	1·2	0·76
After 3 hours - - -	1·2	0·70
After 4 hours - - -	1·2	0·70
After 5 hours - - -	1·2	0·70
After 6 hours - - -	1·2	0·70

5. Cotton (piqués, ribbons, etc.), lime-boiled, and in first lye-boil, with 5 per cent of caustic soda on weight of fabrics.

Boiling at 118° C	Degrees Baumé.	Alkalinity.
Fresh lye - - -	3	1·90
After 2 hours - - -	2·3	1·50
After 4 hours - - -	2·4	1·35
After 6 hours - - -	2·3	1·28
After 8 hours - - -	2·3	1·18
After 10 hours - - -	2·2	1·12

6. Cotton (piqués, ribbons, etc.), in second lye-boil, with 5·7 per cent of salt of soda on weight of fabrics.

Boiling at 118° C.	Degrees Baumé.	Alkalinity.
Fresh lye - - -	2·6	1·80
After 2 hours - - -	2·4	1·66
After 4 hours - - -	2·3	1·59
After 6 hours - - -	2·3	1·45
After 8 hours - - -	2·2	1·40
After 10 hours - - -	2·2	1·29

It will be observed from these tables that it is useless to prolong the boiling beyond a certain limit, after which the lye is almost without further action. Seven to eight hours boiling answers for the lye-boils which precede the chemick and four hours for those which follow. Moreover, it will be seen that the lyes of the first boilings may be run away, as their alkali is almost exhausted, but that it is advantageous to collect the other lyes, which still contain 50 to 70 per cent of the soda present in the original lye. When the boiling is finished the gravity has not diminished, sometimes even it has increased, on account of the colouring principles dissolved in the lye. Fresh lyes are employed for those fabrics which are nearest to white, and old lyes are used for first boilings after the necessary quantity of soda has been added thereto to replace that which has been absorbed.

Examples of various methods of bleaching linen goods in which the use of Mather's keir plays an important part are given in chapter XVII., pp. 272 *et seq.*

Similarly various methods of bleaching cotton goods in which Mather's keir also plays an important part are given in chapter XIX., p. 284.

Table showing strength of aqueous solutions of carbonate of soda of different densities:—

Density.	Baumé.	Twaddell.	Percentage of Contents of		One Cubic Metre contains in kilogrammes, or 100 gals. contain in lb.	
			Na_2CO_3 .	Na_2CO_3 10 Aq.		
1'007	1	1'4	0'67	1'807	6'8	18'2
1'014	2	2'8	1'33	3'587	13'5	36'4
1'022	3	4'4	2'09	5'637	21'4	57'6
1'029	4	5'8	2'76	7'444	28'4	76'6
1'036	5	7'2	3'43	9'251	35'5	95'8
1'045	6	9'0	4'29	11'570	44'8	120'9
1'052	7	10'4	4'94	13'323	52'0	140'2
1'060	8	12'0	5'71	15'400	60'5	163'2
1'067	9	13'4	6'37	17'180	68'0	183'3
1'075	10	15'0	7'12	19'203	76'5	206'4
1'083	11	16'6	7'88	21'252	85'3	230'2
1'091	12	18'2	8'62	23'248	94'0	253'6
1'100	13	20'0	9'43	25'432	103'7	279'8
1'108	14	21'6	10'19	27'482	112'9	304'5
1'116	15	23'2	10'95	29'532	122'2	329'6
1'125	16	25'0	11'81	31'851	132'9	358'3
1'134	17	26'8	12'61	34'009	143'0	385'7
1'142	18	28'4	13'16	35'493	150'3	405'3
1'152	19	30'4	14'24	38'405	164'1	442'4



CHAPTER XI.

SPECIAL METHODS OF LYE-BOILING IN MATHER AND PLATT'S KEIR, AND OTHER METHODS.

"Mather" Patent Keir (New or Improved Model).

THE illustration shows the improved "Mather" Patent Keir extensively used in many of the largest bleaching, printing, and dyeing works in the world. The keir is made in three sizes, holding respectively $1\frac{1}{4}$, $2\frac{1}{2}$, $3\frac{1}{2}$ tons of cloth at one time. It is constructed for a working pressure of 40 lb. per square inch, but is tested to a pressure of 80 lb. per square inch. The cloth is contained in wagons, which, after being filled with cloth already saturated in caustic soda in the bleach house, as just described, are run into the keir, the wedge-shaped door being raised mechanically for the purpose. Each keir is supplied with two sets of wagons, in order that whilst one set filled with cloth is being treated in the keir, the other set may be emptied and re-filled ready for changing as soon as the boiling operation is finished. The changing of $3\frac{1}{2}$ tons of cloth occupies less than ten minutes, instead of taking several hours, as is the case with all other types of keirs. The working of this keir is, therefore, continuous. The circulation is effected by means of a powerful centrifugal pump, and arrangements are provided for reversing at will the direction of the circulation whilst boiling, or during the operation of washing. The horizontal arrangement of the cloth, and the small depths required to be penetrated, ensures the most thorough circulation of the boiling liquor. The heating of the liquor is effected both by means of direct steam injected through perforated pipes, and by indirect steam passing through a coil pipe.

placed in the bottom of the keir. A modification of the keir is also made with an *outside* multitubular heater, instead of the internal radiating pipes. The door joint is made tight by

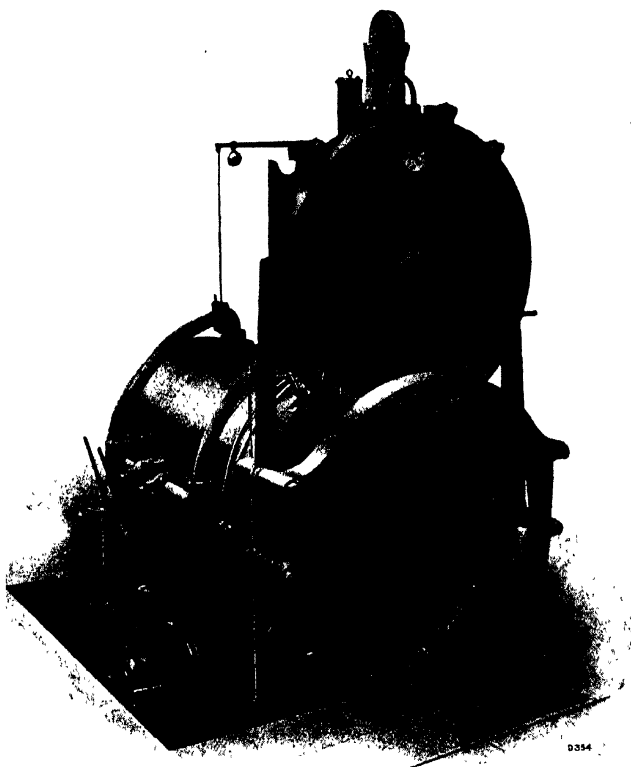


FIG. 27.

means of a single cam and lever without requiring the adjustment of any bolts.

It will be seen by referring to the accompanying illustrations that the keir is cylindrical, and is placed horizontally. It has a door at one end, which is operated by a mechanical

power-driven arrangement fitted with a friction clutch. In it are laid grooved rails in connection with external rails, by means of which trucks or wagons charged with cloth or other material to be bleached are run into or out of the keir.

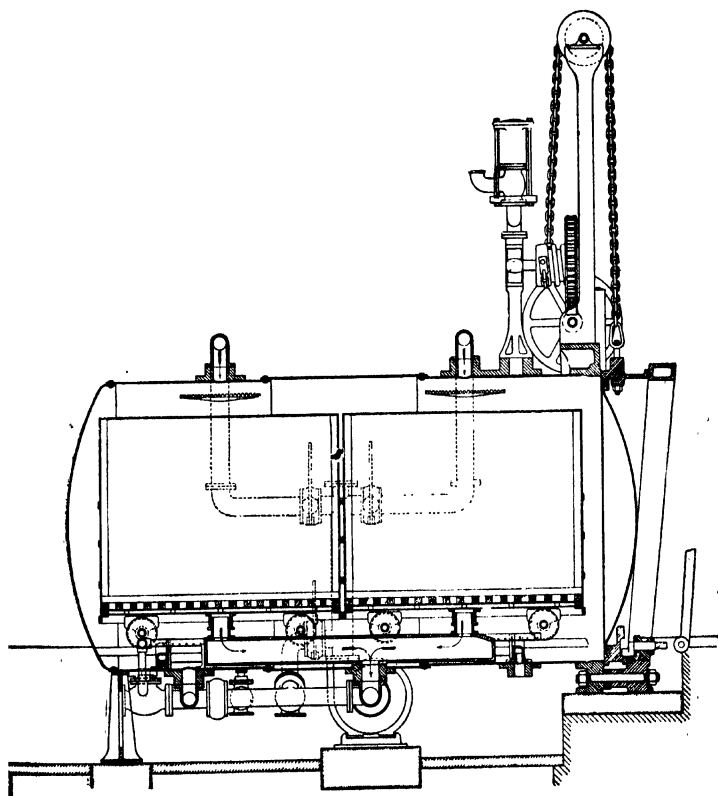


FIG. 28.—Mather's keir (improved pattern).

The wagons are water-tight, and have double bottoms, the upper plates of which are perforated to allow the circulating liquor to pass into the cavities between the plates; from the bottom plates (which are not perforated) telescopic pipes

project downward, and, when the wagons are in position in the keir, make automatic connection with a pipe fixed longitudinally in the bottom of the keir. This longitudinal

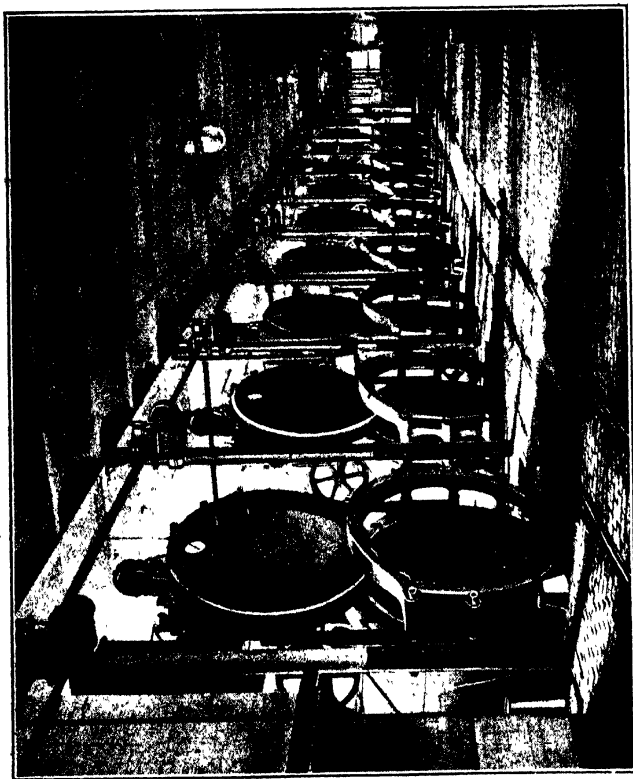


FIG. 29.

pipe also connects with a pump, by means of which the liquor is drawn from the wagons and delivered through the crown of the keir on top of the wagons, whence it passes through the material being bleached, partly by gravitation and partly by suction, again into the pump, the force of the liquor falling

upon the cloth being broken by dash plates or spreaders placed in the roof of the keir under the outlets of the delivery pipes. A connection is also made between the suction side of the pump and the body of the keir to utilize the liquor with falls outside the wagons.

The delivery pipes from the pump are fitted with gauge glasses to show the flow of the liquor.

The washing of the material may be effected in the same manner, or in the reverse direction.

The circulating liquor in the keir is heated by a coil pipe laid in the bottom, the condensed water from which is drawn off outside so as not to dilute the liquor. There is also a perforated pipe to boil by direct steam. Another arrangement of heating the liquor which is frequently adopted is by means of indirect steam in an external multitubular heater.

The hauling of the wagons is effected by means of a revolving capstan and chain, for which there are guide pulleys in suitable positions, and turntables at the points where the lines intersect.

The door is wedge-shaped and fits into a frame, the two sides of which are inclined, so that as the door descends it is wedged towards the end of the keir, and is locked in position by a cam and lever.

The keir is now made suitable for working a pressure of 40 lb. per square inch and is always tested to a pressure of 80 lb. per square inch, both with steam and water, before leaving the works.

Tassel's Keir.—Tassel, a French engineer, has recently invented a keir which works under conditions analogous to Mather and Platt's (of Manchester) keir. Tassel's keir is made by the well-known firm of Fernand Dehaitre, Paris, and according to Tailfer is used in several bleach works, where it gives entire satisfaction. This keir is intended for the lye-boiling of fabrics in an atmosphere of steam, that is to say, out of contact with air, and in certain liquids. It is particularly intended for lye-boiling with caustic soda, because it allows of the perfect washing of the fabrics, both in the hot

and in the cold, without taking them out of the keir. By a peculiar arrangement it is only necessary to use but a small quantity of liquid, about 1000 litres. Consequently, the use of the keir is very economical from the point of view of outlay on chemicals. The plant consists of two keirs, one fitting into the other. The outside keir is provided with a lid closed by bolts and nuts. The inside keir is portable, and may be taken out of the larger keir and run on to a special truck. A centrifugal pump keeps up perfect circulation. When being charged the portable keir is placed on a truck and filled with fabrics in coils or bands, either directly or after being saturated in a special machine. Owing to the circular form of the keir, the fabrics can be spread in it very regularly, a condition absolutely essential to the regularity of the lye-boiling, which can hardly be obtained with horizontal plant. When at work the centrifugal pump circulates the liquid. This, whilst forming a layer above the fabrics so as to prevent them from coming in direct contact with the steam, does not do so, however, without traversing the mass, which not only effects a perfectly regular washing, but it does so without using more than the quantity of water strictly necessary for the working of the pump and the boiling. The liquid only rises to a very small height between the keirs, and all the free space is filled by steam. It will be understood that under these conditions it is necessary for the inside keir to be perfectly tight, a result easily obtained with this kind of keir, and only with very great difficulty in a convex-sided wagon, the faces of which are joined together by lead joints, which the caustic soda attacks in the end. In order to wash with hot water, a jet of boiling water is pumped in so as to fill the whole of the outside keir; the strength of the liquid is thus reduced. The liquid is then run off, leaving only the quantity necessary to work the pump. By repeating this operation a second time the lye is so reduced that the air has no injurious action on the fibre. Washing in the cold is effected through the lower part of the inside keir. By a suitable manipulation of valves the circulation is reversed. The cold water pumped from

the main is circulated under the mass of the fabrics, passes through them, filling the portable keir, and running away at the top into the intervening space escapes through an exit tap. In twenty minutes the fabrics are perfectly lye-boiled, an operation which cannot be effected with the ordinary machines in less than two hours. By using two portable keirs per fixed keir, they may be charged during the working of the keir; the production is thus doubled. When the amount of bleached fabrics does not exceed 1500 kilogrammes (say 3375 lb.) daily, it is not necessary to remove the portable keir. It is left in the fixed keir and the keir is charged and discharged on the spot as in the case of an ordinary keir. An economy is thus effected in the cost of the first laying down of plant and in the price of the washing machines. With two movable keirs, 3000 kilogrammes (say 6750 lb.) may be treated. In fact a portable keir, charged beforehand, may be brought into the fixed keir first thing in the morning, then the goods boiled for four hours, and washed in the keir for one hour and a half. During the time this is going on a second portable keir is charged beforehand, which immediately replaces the first, and the operations thus go on continuously. The arrangements for handling movable keirs may be rendered more easy by means of a crane revolving on a pivot and used for several keirs, and a service of wagons carrying the portable keirs to the washing machines from the lye-boiling and to the saturating machines for the lye-boiling. As is customary in the Irish bleach works, the keir is fixed so as not to project more than about 1 metre above ground. The movable keir having a depth of 1.77 metre (say 69 inches) for 1500 kilogrammes (say 3375 lb.), it can easily be manipulated in buildings of average height. In larger establishments the keirs are increased in diameter but not in height. The inside keir is indispensable for the safe use of caustic soda in concentrated solution. In fact, in an ordinary keir, containing at least 7000 litres (say 1540 gallons) of water for 1500 kilogrammes (say 3375 lb.) of fabrics, about 18 kilogrammes of caustic soda per cubic metre (say 18 lb. per 100 gallons) would be re-

quired—126 kilogrammes (say $2\frac{1}{2}$ cwt.) of alkali per operation, which would come to the excessive cost of 35 francs or 28s. per operation. With Tassel's plant with interior keir 1000 to 1500 litres (say 220 to 330 gallons) only of liquid are required, because all that is necessary is for the fabrics to be prevented from coming in contact with the steam, and as they are piled closely a small quantity of liquid suffices to protect them. Only enough liquid to work the pump, and no more, is left in the intervening space. This small quantity of liquid contains on an average about 50 kilogrammes (say 1 cwt.) of caustic soda, and forms a concentrated lye-boil capable of yielding a good and economical lye-boil costing about 6 francs (say 4s. 9d.). Moreover, as caustic soda is attended with the risk of damaging the textile fabrics unless prevented from coming in contact with air, it is necessary at the end of a lye-boil to bring the fabrics from a temperature of 110° C. to the ordinary temperature. This last operation can only be done with the interior keir, the arrangement of which alone allows of running off the liquid whilst preserving the fabrics from contact with the air. The manner of performing the washing has been already indicated.

Summing up, by using Tassel's keir concentrated caustic soda lyes may be employed without injuring the fabrics, and thus perfect bleaching is rapidly and economically obtained with a less costly plant than that involved by the horizontal machines at present in use, and with greater facilities for making joints.

Weiss' Keir.—Circulation, which is one of the most important factors of bleaching, is effected in all ordinary keirs by pouring on the materials to be bleached the lye drawn from the bottom of the keir. The liquid, which then traverses these materials by its own weight, is brought back by the pump and poured over them once more. A serious drawback arises from this method of working. Even if the fabrics are somewhat loose in texture, the liquid passes through very slowly and often irregularly. Certain parts, according to their density or the method of stowing in the keir, do not allow the liquid to pass so

well as others. Moreover, the liquid poured on the top of the pieces, weighting them down, tends to crush them and to pack them more and more tightly, so much so, that the longer the operation lasts the less active is the circulation. To compensate to some extent the slowness of circulation it is necessary to use highly concentrated solutions, which in the case of caustic alkalies have the serious drawback of being dear, and the still more grave one of being dangerous for the fabrics if the least trace of air remains in the keir, the latter running the risk of being burned. Moreover, the fabrics undergo a certain mercerization which shrinks them more or less. Now every bleacher knows that it is very difficult and, in all cases, long and costly to expel air from the bleaching machinery in use up to now. The volume of air remaining in the keir even after the introduction of the lye is considerable. This volume amounts in certain keirs of an average size to several cubic metres, for the space occupied by the fabrics and by the lye can only be a fraction of the keir. This air, essentially injurious, should be expelled before starting the pressure, which can only be done in all the keirs existing up to now by a long operation causing much loss of steam, or the use of costly pumps, always yielding, however, an uncertain result. In the keir patented by Robert Weiss all these causes of irregular working are completely and safely avoided, and this keir is the only one which, under a small volume, treats the largest quantity of fabrics, for by certain arrangements the keir can be completely filled with fabrics, unspun textile matter, or yarn.

Description.—The keir comprises a vertical autoclave with circulation by pump and a tubular re-heater. It is characterized by compensating reservoir, intercalated between the pump and the top part of the keir and placed at a higher level than the keir. This reservoir contains sufficient liquid to maintain the keir completely full, so much so, that the fabrics cannot come out of the liquid, and that the air is entirely expelled. This reservoir, being in simultaneous communication with the top and bottom of the keir, the liquid exercises an equal

pressure on the top surface and the under surface of the mass to be bleached, thus avoiding any abnormal packing, and permitting an alternative circulation in either direction by the manipulation of a single tap. Different arrangements and combinations of piping and taps enable the different transfers of circulation to be carried out. If need be, the impurities carried in the circulation are removed by a filter.

Charging the Keir and Circulation.—The charging of the keir being done in the ordinary manner the lid is closed; the lye introduced through the bottom of the keir by means of the pump displaces the air in front of it in proportion as it rises, so much so, that when it reaches the top of the keir all the air has been expelled, for this patent keir is claimed to be the only one which works absolutely full of liquid. The liquid continuing to run into the keir, the excess flows out by the top pipe placed on the top of the lid, rises in the compensator, and when about half-way up a quarter of a turn given to a three-way tap stops the flow of liquid and establishes the interior cycle of circulation. Circulation is thus effected from top to bottom by compression, the pump forcing the liquid to pass through the fabrics, and, whatever may be the duration of the operation, the fabrics are never crushed, and the quantity of lye which passes through in the same time is always the same.

Heating.—Circulation begun, the steam taps are turned on to heat the lye. Heating is done entirely outside the keir by radiation in a tubular heater with great heating surface, and by bubbling the steam directly into the compensating reservoir. Owing to this method of heating the goods never come in contact with the steam, and can only be deranged by a blast of steam like what occurs in certain other keirs. The hottest lye never comes in contact with the fabrics. Hence an exceedingly gentle and constantly gradual though very rapid heating. The hot liquid charged by the pump, always drawn by the pump into the compensator, is sent by compression into the keir and drives before it the cold or less hot liquid which, in its turn, passes into the tubular heater and

through the compensator, and there heated, is again drawn by the pumps, and so on. By giving a quarter of a turn to the four-way tap the circulation is reversed from top to bottom.

Processes.—All the chemical processes are used with equal success. Lime, caustic soda, rosin and soda, carbonate of

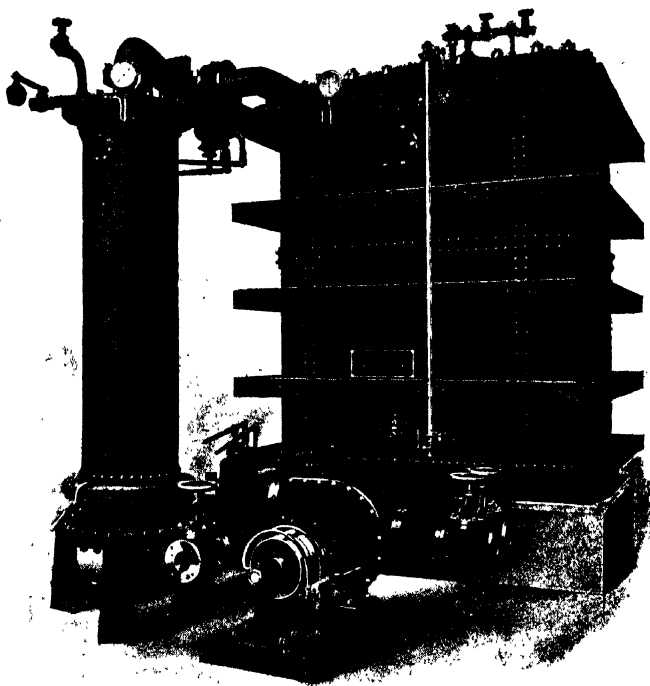


FIG. 30.—Huillard's patent open width bleaching keir (Mather and Platt).

soda, "lessive Phénix," and a small compression pump enables chemical products to be introduced when it is working even at the greatest pressures.

"Huillard Patent Open" Width Bleaching Keir.—Within the past few years considerable attention has been given to the bleaching of cloth in the open width, because it was felt

that if a successful keir was constructed for the purpose, it would "bottom" the cloth more thoroughly and evenly than when in the rope state, and would thereby do away with one of the faults of bleaching in the rope state, viz. the unevenness of the bleach, which leaves the cloth in such a condition that yellow streaks running in the direction of the warp are apparent in the "white" goods, and these streaks in certain

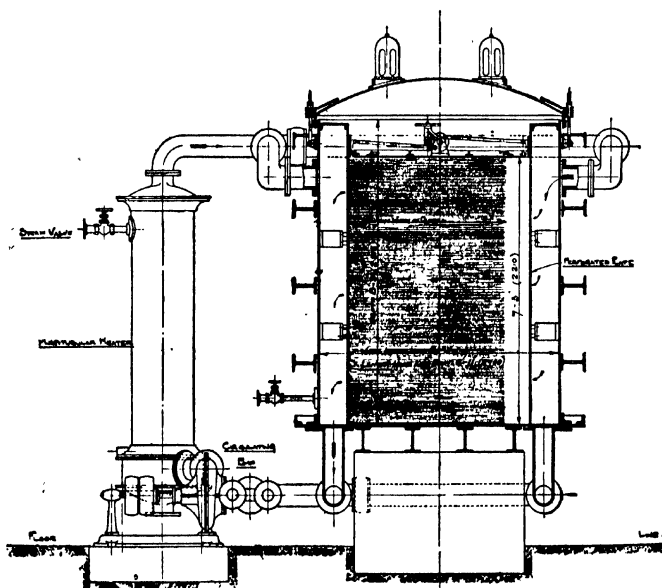


FIG. 31.—Huillard's patent open width bleaching keir (section).

cloths when dyed become much more pronounced and are sufficient to condemn the goods. To overcome this difficulty a successful plan was put forward by M. Alfred Huillard, of the Société Anonyme de Teinture et Impression de Saint Julien, and designed and executed by Mather & Platt, Limited. As will be seen from the illustrations (Figs. 30 and 31) the apparatus consists of the keir proper, which is rectangular in shape and divided into three compartments by means of two perfor-

ated division plates ; a multitubular heater for boiling the liquor and getting up the necessary pressure ; also a pump for circulating the liquor. The cloth, in the form of one wide piece, or two narrow pieces, or one wide and one narrow, is plaited down into the middle compartment of the keir, by means of an automatic travelling winch, and a light cover forced down upon it, and held in position by a special mechanism, the object being to keep the cloth from lifting during the boiling, and also to ensure an even circulation. The keir lid is then closed, the pump started, and the liquor drawn from the mixing cistern and forced through the heater along the pipes as shown by the arrows. It proceeds into the far side compartment, through the cloth, into the near side compartment, and thence back to the pump. By means of the connections provided, the circulation can be reversed, the principle always being followed that the liquor enters at the top of the keir and is withdrawn at the bottom. By this means, and the reversal of the direction of flow, the liquor is forced through the fibres of the cloth, and not merely between the folds. The washing, scouring, and chemicking are all done in the open width in suitable machines of the open soaper type. This fact has an advantage in that the cloth is kept wider than when treated in the rope state and does not undergo any deformation, the weft threads remaining at right angles to the warp.

In actual practice the keir gives the greatest satisfaction with respect to rapid working, the circulation of the bleaching liquor, and the thoroughness of the bleach, and it requires only half the staff for the same number of pieces as the generally used vertical keir for bleaching in the rope state.

The keir will hold about $2\frac{1}{2}$ tons of cloth, and the boiling at 15 lb. pressure takes six to ten hours, according to the strength of the circulating liquors.

CHAPTER XII.

SOAP.¹

Short Description of Soap Manufacture—Action of Soap in Bleaching—Manufacture of Rosin Soap—Manufacture of Olein Soap—Use of White Marseilles Soap—Comparative Cost of the Three Kinds of Soap—Testing Soap—Quality and Quantity of Soaps to Use in the Lye—Soap Lyes or Scalds—Soap Scouring Stocks—Soap Scouring Rubbing Machine.

Short Description of Soap Manufacture.—Soap is the result of the combination of a vegetable or animal oil or fat with an alkali, soda, or potash. The typical soap—that from which all others have been derived—is Marseilles soap, consisting of olive oil and soda lye, with a little tallow to increase the hardness. The manufacture of soap involves quite a host of operations requiring great skill and experience to secure good results, which, leaving on one side the details of the working manipulations, may be reduced to the following. The quantity of lye corresponding to the oil to be operated on is run into a pan and boiled, and the whole oil run in at once; the heat is kept up, but not too great a heat, running in from time to time a fresh quantity of lye into the pan. This first operation is known as saponification.

In the second stage the spent lye is run off by means of a pipe fixed to the bottom of the pan, and the boiling is continued, fresh lye being run in all the time. This is the soap

¹ For full particulars in regard to soap manufacture, see Hurst's "Textile Soaps and Oils," published by Scott, Greenwood & Son, the publishers of this volume.

boiling proper, which is finished when the solidified lye crumbles to powder between the finger and thumb.

The purification comes afterwards; the soap is finished, but it is impure. It is re-boiled with the addition of weaker alkaline lyes, or with brisk agitation of the paste, which is kept in a semi-fluid state. The heavier foreign matters settle down at the bottom, after which it only remains to run the soap into the frames. The marbled soap so frequently met with in commerce has been mixed with sulphate of iron, green copperas.¹ It contains 30 to 40 per cent of water. White soap contains 40 to 50 per cent of water.

Action of Soap.—Soap is very extensively used in bleaching. On the one hand it acts as a solvent of the resinous matter, whilst on the other hand it acts mechanically by facilitating the expulsion of the impurities in the fabric. The soapy waters convert the impurities in the fabric into more or less soluble compounds, which only require to be removed by washing. Soap in lathering renders these impurities more smooth, more gliding, and when the fabric is rubbed they emerge more easily. Marseilles soap, black soap, olein soap, rosin soap are used in bleaching. It is advisable for large bleach works to make their own soap. Rosin soap and olein soap give very good results, and their manufacture will now be described.

Manufacture of Rosin Soap.—Rosin soap is made in a pan made of iron plate and heated by a steam coil. The following are the proportions used:—

Rosin	- - - - -	100 lb.
Caustic Soda, 110° Descroizilles	- - - - -	25 „
Water	- - - - -	100 gallons.

The water and the caustic soda are run into the pan, and brought to the boil so as to dissolve the soda. The muck, which floats to the top in the form of a froth, is removed by a skimmer. The rosin is then run in, stirring all the while, so as to prevent it from settling at the bottom. The heat is kept

¹ An ferruginous or cupreous soap is a dangerous thing to apply to fabrics, more especially fine white material. Mottled soap should therefore be rejected.

up quite gently (simmering) for four or five hours. To know whether a good result has been got, run a little of it into a glass and observe whether it be transparent, or whether it be curdy. When pouring slowly the contents of the glass should string. It should be greasy to the touch.

Manufacture of Olein Soap.—Distilled olein is used. This soap is made like rosin soap. The proportions are the following :—

Olein	-	-	-	-	75 lb.
Caustic Soda, 70°, Na ₂ O	-	-	-	-	15 "
Water	-	-	-	-	100 gallons.

Olein contains petroleum and hydrocarbons, which do not make soap, or at least do not lather, but it would not appear that this is any detriment in the bleaching. It contains iron, which gives to it a blackish colour. This is due to the fact that manufacturers allow it to settle and cool in iron receptacles, during which time it dissolves a certain amount of iron. It also dissolves lead very freely, and this lead imparts to the fabrics a greyish tint, which cannot be got rid of afterwards. This fault is well known to silk and wool manufacturers. Olein contains a greater or less amount of stearine; by allowing the olein to settle the stearine falls to the bottom; stearine lathers. In order to make a good olein soap it is necessary to start upon a clear sample of yellow olein, limpid and not cloudy.

Use of White Marseilles Soap.—Rosin soap, olein soap, and white Marseilles soap are the three varieties of soap preferred for bleaching. The soap may be cut up and dissolved in the water before dissolving the soda. It is very convenient in bleach works to have a solution of white soap prepared beforehand. The soap is dissolved in a special pan for the purpose, and is drawn off by a tap when required to be added to the lye, or any other purpose. The proportions are :—

Soap	-	-	-	-	100 lb.
Water	-	-	-	-	100 gallons.

Before drawing off the soap it must be well mixed, as the

soap falls to the bottom. This mixing is very well done by a steam coil placed in the bottom of the pan. The boiling agitates the mass, and renders it homogeneous. Should the water be calcareous, before dissolving the soap a little caustic soda is added to precipitate lime compounds, because the lime in solution would transform part of the soap into a lime soap insoluble in water, which would appear in the form of curds.

Comparative Cost of Different Soaps.—The cost per litre is got by supposing the quantities indicated are dissolved in enough water to make 1000 litres.

WHITE SOAP.

100 kilogrammes of soap at 75 francs the 100 kilogrammes	= 75'00 francs.
Price ¹ of a litre $\frac{75 \cdot 00}{1000}$ - - - - -	= 0'75 "

OLEIN SOAP.

75 kilogrammes of olein at 50 francs the 100 kilogrammes	= 37'50 francs.
15 kilogrammes of caustic soda at 32 francs the 100 kilogrammes	= 4'80 "
	<hr/>
	42'30 "
Price ¹ of a litre $\frac{42 \cdot 30}{1000}$ - - - - -	= 0'042 "

ROSIN SOAP.

100 kilogrammes of rosin at 15 francs the 100 kilogrammes	= 15'00 francs.
25 kilogrammes of caustic soda at 32 francs the 100 kilogrammes	= 8'00 "
	<hr/>
	23'00 "
Price ¹ of a litre $\frac{23 \cdot 00}{1000}$ - - - - -	= 0'023 "

Recipes for Making Soaps. (1) *Manufacture of White Soap.*—Make a concentrated caustic soda lye and fill the pan to about a third with it. Heat almost to boiling, and add the tallow. Add it in such quantity that, once dissolved, a creamy consistency is obtained: stir gently, keeping up a slow fire. Boil for about four days, and stop when the soap is of the requisite consistency, but do not boil too much, for the soap will become too thick and stick to the sides of the pan. (2) *Another Method.*—Put about 300 lb. of tallow in the pan and run in 22½ gallons of strong caustic lye, keeping up a gentle heat.

¹ In other words, the cost of equal volumes of the dissolved soap is in the ratio of 75, 42, and 23.

Boil for four days and ladle into the frames. The lye may be changed two or three times by running away the liquid portion after cooling the pan. This method yields a very strong soap, but for bleaching one lye is enough; 600 to 700 kilogrammes (13-15 cwt.) of tallow yield a ton of soap. (3) *Rosin Soap*.—Boil the tallow and the soda as before, then add as much pulverized rosin as will make one-fourth of the tallow used, and mix the whole with lye, stirring with a rake. The soap is finished when it becomes solid on cooling, or else when, mixed with a little water, it does not leave a resinous varnish on the skin. Its colour may be deepened by the addition of a little palm oil. (4) *Soft Soap*.—Whale, cod, seal, olive, linseed, and palm are the oils used, with a little tallow. Run a portion of the oil into the pan, bring almost to the boil, then add a weak lye. Bring to the boil and add lye and oil until you have introduced the desired quantity. When you have obtained regular ebullition with good agitation, add a little stronger lye until complete saponification is effected. When the curds have disappeared, and the paste ceases to "bite" the tongue, and spread on a glass plate it presents the requisite consistency, and taken between the fingers it is perfectly smooth, then the soap is finished. Twenty-two kilogrammes (say 50 lb.) of oil and 8 kilogrammes (say 18 lb.) of caustic soda of 100° Descroizilles diluted with water so as to mark 6° to 7° Baumé will yield 50 to 55 kilogrammes (say 1 cwt. to 1¼ cwt.) of soft soap. When potash is used instead of soda a softer soap is obtained.

Soap Testing.—It is very important that the bleacher should satisfy himself as to the quality of the soap which he uses. It may be had on the market at all prices, but owing to the large quantity of water and impurities it is advisable to pay a good price and get a good article. The systematic analysis of soaps is too complicated to be employed by the bleacher. The following method will enable him to make an approximate relative valuation of different soaps. Quicklime is dissolved in water, and after decantation the clear liquid is drawn off and used as the test liquid. Ten grammes of each sample of

soap to be tested are then weighed out, and each of these samples is dissolved in distilled water and the bulk made up to a litre. Then 10 cubic centimetres of the clear lime water are run into a flask of about 100 cubic centimetres capacity. A burette graduated in cubic centimetres and tenths of cubic centimetres is filled up to zero with the solution of the soap to be tested. The soap liquor is then run in drop by drop into the lime water, and the whole is agitated from time to time to see if there be a persistent froth, and the reading is taken when this occurs. The number of cubic centimetres is noted, and the process is repeated on the remainder of the samples to be tested. The soap is first of all converted by the lime into a lime soap, and the lather only appears when this reaction is complete. It follows therefore that the smaller the quantity there is required to be run in to saturate the lime the richer the soap in question is in fatty acids. If in testing three samples of soap the operator has run in, for example, 60 cubic centimetres of the first, 40 cubic centimetres of the second, and 30 cubic centimetres of the third, the conclusion would be that the value of these soaps are in the ratio $\frac{1}{30}$, $\frac{1}{40}$, $\frac{1}{60}$, and if the first soap cost 30 francs the 100 kilogrammes, the second should cost 45 francs, and the third 60 francs the 100 kilogrammes. The practical man can very often determine the quality of a soap by noticing how it lathers.

Quality and Quantity of Soap to Use in Lyes.—It is advantageous to add a little soap to the lyes, because soap emulsifies the substances dissolved by the soda and facilitates their expulsion from the fabrics. Soap may be dispensed with in the first lye; the substances to be dissolved being on the surface are easily removed by the lye. But in proportion as the fabrics begin to bleach, the lye ought to penetrate more intimately into the fibre, so as to dissolve all the substances which have resisted the first boiling; thus the action of the soap helps that of the lye. Provided that the rosin soap be well made, it may be used in all the boilings, but if the rosin has not been well saponified it is deposited on the fabrics and soils them. This necessitates energetic boiling to remove the

stains; acids also cause them to disappear. Rosin soap is yellow, and if the fabrics be not sufficiently washed they retain this tint, and are not so bright as if they had been treated with white soap. The same remarks apply to olein soap, which has a brown colour. There is no risk of spotting, but it leaves a yellow tint behind on the fabrics. In the manufacture of olein soap bright yellow olein ought to be chosen, not dark. Marseilles soap is the best for conferring a bright tint to the fabrics, but its price is very high, and it is only used in the lyes and washings which terminate the bleaching process. The following would be a rational and judicious use of the different soaps. (1) Rosin soap for lyes before chemick; (2) rosin soap for lyes intercalated between the chemicks; (3) white soap for the last boil or the last soaping. The quantity of soap for each lye is not fixed. A good proportion is to run in 30 to 35 litres of liquid soap (say 3 to 3½ gallons per 100 gallons) made as indicated on page 149 for every cubic metre of lye. The proportions by weight are 500 to 600 grammes of soap for 100 kilogrammes of fabrics (say 56 lb. per 1000 lb. or 1 lb. to 1½ lb. per cwt.).

Soap Lyes or Scalds.—When fabrics are almost white they may with advantage be boiled with soap before the last chemick, or even after it before being sent to be finished. Tailfer recommends olein soap but prefers Marseilles soap. Good proportions are 5 to 6 lb. per 100 gallons, which is first of all boiled with 2 lb. of soda crystals per 100 gallons. If completely bleached goods be put in the soap boil, care must be taken to have everything right. The bottom of the vat should be frequently inspected. It is there that the muck and dirt accumulates. Boiling brings it all up and the goods are consequently soiled. The temperature of the soap-bath is kept at between 75° to 80° C. If too high a heat be used there is danger of yellowing the goods. In those works where boiling with soap is the last operation before finishing, the soap-bath is sometimes coloured with a little indigo blue. The goods are then washed, but they retain a very persistent blue cast. The only thing to fear in this process is that the fabrics retain-

ing a little soap may yellow in the soap. Tailfer recommends as a final operation a soap boil instead of a sour in those bleach works where the washing machines are not so perfect as not to leave a trace of acid. When the coarse sheeting of the Nord or of Normandy is being treated it is very difficult to remove all traces of acid by washing. A soap boil as a last operation presents no such difficulty.

Moreover, it is customary to boil the fabrics with soap before putting them through the lyes which follow the chemick. But this is an operation which there is a tendency to suppress, because it is rather costly in labour and in soap. It is far better to pass the goods to the fulling mill or the dash mill; the expense of soap is the same, and its action is more energetic.

Soap Scouring Stocks.

This machine comprises:—

1. A wooden tub mounted on a pivot and rollers and girdled in its lower part by a toothed collar. A pinion gearing into this collar imparts to the keir a circular motion causing it to make one and a half to two revolutions a minute.

2. A series of wooden stocks arranged in the same line of action, along the axis of the tub, and which as they successively fall scour the fabrics. They are worked by cams mounted on a horizontal shaft and arranged in such a manner that the wooden stocks fall one after the other. This shaft makes forty revolutions a minute; in this way each stock strikes the fabrics forty times a minute. Each stock weighs 6 to 10 kilogrammes (say 13 to 22 lb.).

By means of a special arrangement all the stocks may be kept hoisted up during stopping time. A steam pipe in the centre heats the soap-bath, and keeps the temperature about 60° C. during the operation.

Olein soap answers very well—50 litres of olein soap per cubic metre of water. The trough is about half-filled, say to a height of about 16 inches. The fabrics should not be piled too high up, because the action of the stocks will not

affect those at the bottom. Each batch is operated on from three-quarters of an hour to one hour. The fabrics are then placed on a perforated wooden platform, underneath which is a soapy water reservoir. This soapy water is used in a subsequent operation with the addition of fresh soap to the bath.

The washing of fabrics in the stocks with soap answers very well for delicate fabrics, which it is to be feared would be injured on the rubbing boards. There is not much risk of danger in the stocks if they be kept in good condition.

Soap Rubbing Board Washing Machine.—The principle of this machine is to cause the fabrics impregnated with soap to pass between two corrugated wooden boards, one of which is fixed, whilst the other has a to-and-fro motion.

The upper board is propelled by a shaft attached to a crank, and the to-and-fro movement of the board rolls the fabrics first one way and then the other. The fabrics dip into a wrought-iron trough filled with soapy water. The fabrics are drawn by the rollers in front of the scrubbing boards: the traction speed is 0.60 metre to 0.80 metre (say 2 to 2½ feet) per minute. The shaft which imparts the to-and-fro motion to the boards makes sixty-five turns per minute. The boards are made of beech wood and are in two parts. The corrugated portion is replaced when worn. The corrugations should be well rounded so as not to cut. The rubbing boards should be often inspected to see whether the grooves do not present any rough surfaces, asperities, or unevenness which would destroy the fabrics. The boards of the rubbing board machines with troughs are coupled together two and two, and the gutters inclined at an angle of 45°. The gutters of the upper board are inclined in an inverse sense to those of the lower board.

Rosin soap or olein soap is used; white soap would be too dear. Fifty litres of soap are used per cubic metre of water (say 5 gallons per 100 gallons), and 2 kilogrammes of carbonate of soda (2 lb.). A steam pipe placed below the false bottom keeps the temperature up to 70° C. Once or twice daily 20 litres of soap are added per cubic metre of water (say 2 gallons per 100 gallons) to replace that which has been used

up by the fabrics. The same soap liquor, strengthened as it becomes exhausted, lasts several times. It is renewed when too dirty. The fabrics are passed through the rubbing boards before the lye-boil between the chemicks. This operation softens the fabrics, opens the fibres of the yarn, and exposes all

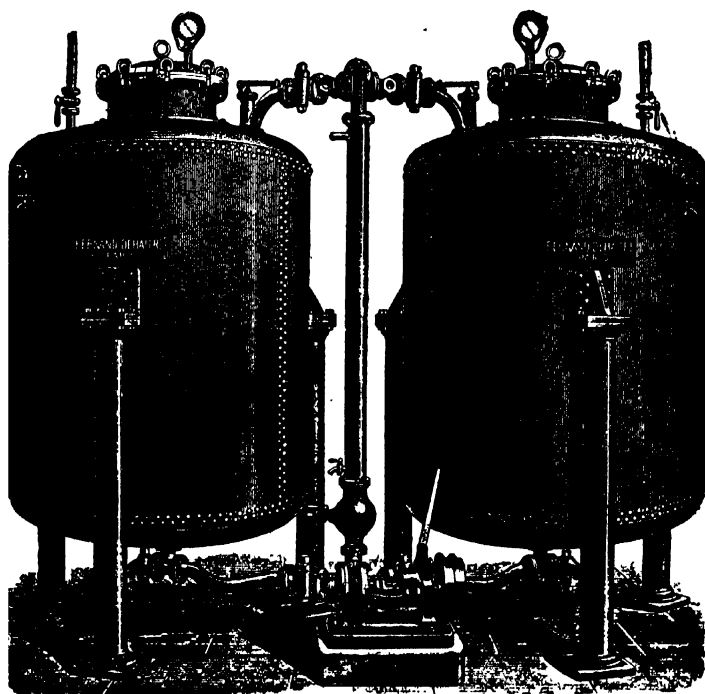


FIG. 32.—Pair of pressure keirs working conjointly with pump and reheater.

their parts to the action of the bleaching agents, or to that of the atmosphere when exposed on the bleaching green. There need be no fear that the rubbing boards will injure the fabrics. Very fine goods are passed through them without sustaining any injury, provided that they are drawn gradually through between the rubbing boards in a uniformly regular manner, which can be obtained by well regulating the machine. Fine

narrow fabrics are doubled, or two are passed at the same time. Special care should be taken in regard to the consecutive joining together of the pieces so as not to draw the knots too tight, because the rubbing boards would cut the fabrics at that point. The number of times that it will be necessary to pass the fabrics through this machine cannot be determined beforehand; it depends on the quality of the goods and the degree of whiteness aimed at. For a fine white, tissues with a bright foundation are passed two or three times, but in the case of a dark foundation they must be passed four to six times, following each wash on the rubbing board machine with a lye-boil. The passage through the rubbing boards shrinks and lengthens the fabrics; they must be stretched in the direction of their width in finishing.

Lye-Boiling with Rosin Soap.—The pieces, 12,000 lb. (6000 lb. in each keir), are fed into keirs working in pairs. After the manhole lids have been screwed on tightly, steam is turned on to expel air and cold water and to heat up the cloth. The rosin soap tap of one of the keirs is opened and the rosinate of soda liquor (rosin soap), made from 770 lb. 58 per cent soda ash, 214 lb. rosin, and 1400 gallons of boiling water, is run in from the measuring cistern. By manipulating the taps the rosinate of soda (rosin soap) liquor is driven from one keir to the other for seven hours by steam at 40 to 50 lb. pressure to the square inch. Steam is then turned off and the spent liquor run off, steam being turned on once more to completely expel it. When all the spent liquor has been run off, the steam taps and draw-off taps are closed and the liquor tap is opened to admit soda ash liquor from another tank.

CHAPTER XIII.

BLEACHING ON GRASS OR ON THE BLEACHING GREEN OR LAWN.

- I. *The bleaching action of exposure on a grass lawn or green—*
 2. *Methods of spreading out on the bleaching green—*3. *Precautions to be taken—*4. *Arrangements and laying out of the bleaching green—*5. *Watering—*6. *The necessity for bleaching on the green.*

1. *The Bleaching Action of Exposure on the Bleaching Green.*—Four elements act concurrently in the bleaching of fabrics exposed on the bleaching green, viz. (1) light, (2) air, (3) moisture, (4) the nature of the grass.

The most energetic bleaching agent is light, more especially sunlight. Fabrics bleach more rapidly when exposed on a sunny day than in dull weather, and better by day than by night. Accordingly, when fabrics, woven or spun in part of coloured materials which are to be preserved intact, have to be bleached, they must not be exposed to direct sunlight. In summer they are lifted during the day or covered with other fabrics. They are only exposed during the morning, the evening, and the night. By exposure is meant that the linen cloth is taken and spread upon the bleaching green for four, six, or eight days, according as the routine of business calls for the return of the cloth in order to undergo further operations.

When the cloth is laid out upon the grass, it is the oxygen of the air which acidifies the colouring matter; for which reason, the dew, which contains much air rich in oxygen, singularly accelerates the bleaching process. Should the goods, however, be left too long on the grass, oils and fats

absorb certain elements and then become insoluble in lyes. The bleacher must ascertain the resistance of the colour to light, and withdraw it at the proper time. The state of the atmosphere has a wonderful influence. Dry weather is not favourable; no more is rainy weather. Slightly moist weather, like that when the dew falls in the morning, suits best. The bleacher cannot alter the state of the weather, but the above remarks explain why the climate of certain countries is more favourable for bleaching than others. Ireland, so famous for its white linen, is endowed with a moist, temperate climate and uniform equable temperature. It owes these advantages to the sea and to the flow of the Gulf Stream along its coasts. Brittany, in France, possesses similar advantages. Finally, plants also play their part. In fact, if instead of spreading the fabrics on the green they be hung upon lines or cords, they do not bleach nearly so well. We do not know exactly how grass assists in bleaching; it is in all probability due to the oxygen and carbonic acid which they disengage, as well as to the moisture which they yield to the fabrics. Summing up, the bleaching action of grass exposure is very probably due to oxygen, but above all to ozone, which is oxygen in a particularly active state. Light, heat, and moisture assist either in the transformation of oxygen into ozone, or to cause it to penetrate more intimately into the tissues of the fabric. It is necessary to remark, however, that the oxidizing action of grass bleaching has not only the effect of transforming coloured matters into colourless products, but it also transforms them into substances more easily dissolved by lyes. Suppose, for example, two lots of fabrics be taken, of which one only has been exposed on grass, and that they are washed separately, it will be seen when the boiling is finished that the lye of the lot exposed on the grass is charged to a much greater extent than the lye of the other lot, thus proving that its dissolving action is much more considerable.

2. *Method of Spreading.*—The fabrics are transferred either in trucks or on men's backs to the place where they are to be spread out. A workman takes hold of the sheet by one

end and draws it out so that it is extended to the whole of its length. Then the piece, held at both extremities, is untwisted and fixed in such a manner that it is thoroughly spread out. In the case of delicate fabrics, such as handkerchiefs or cambrics, care must be taken not to stretch them too much, for fear of breaking the selvage. If the piece be very long, a workman is placed in the middle to support it and prevent it being too much stretched. Sometimes it is preferred not to spread out the piece throughout all its length; it is refolded back upon itself, and the second part is spread alongside the first. Coarse sheetings are fixed by pegs at their extremities so as to hinder them from rolling with the wind. Delicate sheets must not be fixed, as the wind would tear them. Sometimes the pieces are kept stretched by wooden pins attached to cords at different intervals. Independent of the risk of tearing the goods, this complicated method is rarely employed in consequence of the heavy working expenses which it entails. Coarse sheetings remain on the bleaching green four or five days; light fabrics two days. This would appear to be the most suitable length of time. But bleachers are often guided in this respect by the extent of their bleaching green and by the progress made in the bleach works.

3. *Precautions.*—The wind rolls light fabrics into the form of cords or ropes. In such a case, if possible, they should be spread out again. It is a rather costly piece of handiwork, but it is money well spent, because the fabrics thus rolled up do not benefit by any further exposure on the grass. The fabrics are often soiled by stormy rains spreading over them the dust carried along by the rain. The fabrics act like a sieve, allowing the water to pass through whilst retaining the dust. They are also often soiled by the wet, muddy ground. These spots are difficult to remove, especially from light cross-warped fabrics. They must be washed before the mud dries; sometimes soaping is necessary, or even hand rubbing with a brush. The further the bleaching process is advanced the more injurious are these spots. The best remedy is to prevent them from occurring. Preference should therefore be

given to the green best covered with sward for the bleaching of fabrics already well advanced to whiteness. If bad weather be feared they should be taken in from the bleaching green. Coarse sheetings should be hung up on pegs ; water and dust will run down and not soil them. Fabrics soiled on the bleaching green are not treated with lye without previous washing, because the lye at a high temperature would bake the mud and it would then be still more difficult to remove afterwards. The effects of rain are not always identical in every instance. They vary according to the direction of the wind. The bleacher ought therefore to carefully observe the injurious effects of rain and make his arrangements accordingly to prevent them.

4. *Arrangement, Laying-out and Upkeep of Bleaching Greens.*

—Lawns intended for bleaching greens ought to receive special attention. They ought to have a good sward, because fabrics exposed on the naked earth are soiled with mud. They ought to be mown often, for light fabrics, spread upon long grass, soon roll up and do not bleach. The ground ought to be slightly inclined, with a uniform slope, or arched, in such a manner that the water easily runs away : if not, it will remain in puddles, and thus cause mud spots. Moreover, in winter the fabrics will be frozen to the grass, and in detaching them carelessly will be torn. Plants, the flowers of which soil the fabrics, must be weeded out. Gravel and pebbles must be removed. The fabrics rolled by the wind retain these in their folds, and when they are passed through the washing machines are the cause of accidents. The bleaching greens are crossed by roads along which the fabrics to be bleached are brought close to the spot on which they are to be spread. Along the sides of the road wooden frames or stone tables are placed to receive the fabrics. If wooden frames be used care must be taken that the heads of nails do not project, otherwise they would soil the fabrics with rust and tear them. Workmen should not walk on the fabrics, especially with shoes or clogs with nails. This is a cause of tearing and spots of iron rust. When dealing with strong sheeting, like that of Normandy,

difficult to tear, lines of posts are fixed into the bleaching green, about 3 feet 3 inches to 4 feet in height and about 10 feet apart. The distance between one row and another is a little greater than the width of the sheets to be spread out. These posts are used to raise the pieces in rainy weather, so as to prevent them being soiled by the dust of the atmosphere or the mud of the ground. At the end of each row of large posts, two posts 10 inches high are placed, to which the piece of fabric is attached by its four corners, so as to keep it well spread on the grass.

5. *Watering*.—In some bleach works the fabrics laid on the green are watered. This is a costly piece of manual labour, and requires a special arrangement of small streams of water. The greens are intersected by a series of small parallel streams, 20 to 25 yards apart. The pieces are spread out in the intervening spaces, and a workman, provided with a rose of a special form, projects the water, which falls in the form of a shower of rain on the fabrics. This is a highly beneficial operation, because when the fabrics are dry they bleach to a much smaller extent than when they are moist. Moreover, when light fabrics are spread on the green, the slightest wind causes them to roll, whilst should they be moist they remain spread out much better. An expert workman can water in an hour a surface of over 3000 square yards. The work can be done by boys. The author has seen a special form of instrument for watering employed with success. It consists of a piece of wood $7\frac{1}{2}$ feet long, of which one part is scooped out in the form of an elongated spoon, whilst the other contracted part serves as a channel. The worker manipulates quickly the turn of the wrist to project the water.

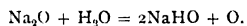
6. *Necessity for Exposure on the Bleaching Green*.—Cotton fabrics are generally bleached without exposure on the green; but up to the present time no means have yet been discovered by which this operation may be dispensed with in the case of linen. The method used by Dr. O. Fröhlich for bleaching hanks of linen yarn by means of ozone, and thus dispensing with grass bleaching, is given in the last chapter of this

volume. It is questionable whether, if it were likewise applied to the bleaching of linen fabrics, grass bleaching might be dispensed with. In any case, with the processes in common use, if the fabrics be not exposed on the green, they remain yellow, and this tint becomes more apparent when the fabrics have been warehoused for some time.

CHAPTER XIV.

BLEACHING BY PEROXIDES, PERBORATES, AND BY OZONE.

Peroxide of Sodium, which has the formula Na_2O_2 , is prepared either by the action of oxygen on sodium or by the addition of hydrogen peroxide to a concentrated solution of soda. It is a white pulverulent substance soluble in water, with an alkaline reaction, decomposing by hot water, yielding soda and oxygen.



Owing to the ease with which it yields up its oxygen it is a powerful oxidizing agent. This property is utilized, especially in analysing chrome minerals. Acids convert sodium peroxide in acid solution into the corresponding soda salts with liberation of oxygen. It may be estimated by utilizing this reaction, adding at the same time a catalytic agent to complete the disengagement of gas.

Valuation of Sodium Peroxide.—In determining the value of sodium peroxide the chief criterion in most cases is the amount of oxygen it is capable of liberating, no matter whether such oxygen originates in sodium peroxide or higher oxides. According to Lasker, the Archbutt Grossman gas volumetric method is the only suitable one for determining the active oxygen present in sodium peroxide, the permanganate method being unreliable. The iodometric methods of Ruff also furnish merely approximate results.

Process.—Water alone is not sufficient to decompose peroxide of sodium, but by adding a small quantity of nitrate of cobalt—an action analogous to that exercised by this salt on hypochlorite in the preparation of oxygen in laboratories

—all the active oxygen is liberated and may be collected under a bell jar.

In actual practice a Lunge's volumeter is used of about 140 cubic centimetres capacity; 0.5 to 1 gramme of peroxide of sodium is weighed and placed in the exterior flask, taking care to work quickly and in a very dry apparatus. Into the interior vessel 20 cubic centimetres of $\frac{1}{10}$ sulphuric acid containing two or three drops of a saturated solution of nitrate of cobalt are run. The apparatus being well corked the acidulated water is reversed several times on the peroxide, and the volume of gas disengaged measured. One gramme of peroxide of sodium disengages about 130 cubic centimetres of oxygen, say 0.1857 gramme. One cubic centimetre of oxygen at 0° and 760 millimetres pressure weighs 0.001429. The pure peroxide would disengage 143.34 cubic centimetres. The available oxygen is deduced from the number of cubic centimetres of oxygen found by a simple rule of three. The determination may also be effected by the use of an apparatus analogous to that used for determining the carbonic acid in bicarbonate of soda, the necessary calculations being made from the figures given above.

Estimation of Total Alkali in Peroxide of Sodium.—Dissolve 0.5 gramme of peroxide of sodium in distilled water, boil and titrate with semi-normal sulphuric acid. One gramme of pure peroxide requires 51.2 cubic centimetres of semi-normal sulphuric acid $\frac{N}{2}$. If N centimetres of semi-normal acid $\frac{N}{2}$ have been used, we get

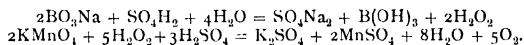
$$\text{Na}_2\text{O}_2 \text{ per cent} = \frac{200 N}{51.2}.$$

If sodium peroxide be used in analysis as an oxidizing agent, other impurities, Cl, H_2SO_4 , Al_2O_3 , which might falsify the analysis of the substance oxidized, must also be determined. Where impurities are found it is important that a weighed portion of the oxidizing agent be used, and to deduct from the analysis the amount brought by the reagent. The estimation

of chlorine sulphuric acid and alumina is effected by well-known methods.

Perborate of Soda.—Perborate of soda (like other perborates a salt of perboric acid) is a white powder slightly soluble in water and endowed with oxidizing properties analogous to those of hydrogen peroxide owing to the facility with which it parts with its oxygen. It is generally prepared by mixing boric acid and peroxide of sodium in aqueous solution. It is deposited in virtue of its slight solubility. Perboric acid which has not been isolated differs from boric acid in containing an extra atom of oxygen.

Estimation of Perborate.—Its property of reducing permanganate in acid solution, with liberation of oxygen, is utilized; 2 grammes of perborate reduce 10·3 cubic centimetres of normal permanganate, which corresponds with 4·12 per cent of active oxygen. The reaction may be expressed thus:—



The titration is made on 2 or 5 grammes of the perborate; add 50 cubic centimetres of distilled water, then 50 cubic centimetres dilute sulphuric acid (100 to 150 grammes per litre) and then run in N cubic centimetres of a normal solution of permanganate until a slight rose coloration appears. The ratio $\frac{N}{10\cdot3}$ gives the perborate per cent if 2 grammes of substance

have been operated on. One hundred parts of pure commercial perborate, $\text{BO}_3\text{Na}_4\text{Aq}$, contain 10·38 of active oxygen. If it be desired to estimate the available oxygen, to avoid all calculation a permanganate solution containing 5·64 grains per gallon should be used, 1 cubic centimetre of which corresponds to 1 cubic centimetre of oxygen at 0° C. and 760 millimetres, 1 litre of oxygen at 0° C. and 760 millimetres weighing 1·43 grammes; the oxygen by weight can be calculated therefrom. The usual tests for impurities—chloride, sulphate, nitrate—are made.

Properties of Perborates.—Several perborates are known, all of them to a certain extent stable, even when they contain

one or more molecules of water of crystallization, though heat or a trace of water of solution suffices to cause decomposition. Like peroxides they readily part with the surplus atom of oxygen which in the nascent state combines with water to form hydrogen peroxide, H_2O_2 . Brahat and Dubois exhaustively examined the perborates. They found *inter alia* that on treatment with cold concentrated sulphuric acid the perborates furnish highly concentrated hydrogen peroxide, which decomposes forthwith with liberation of ozone. Perborates liberate iodine from potassium iodide and yield perchromic acid with bichromate and sulphuric acid. When added to sulphuric solutions of titanous or vanadous acid, perborates produce a blood-red coloration. They decompose permanganate, KMnO_4 , which thus forms a reagent by which their active oxygen content can be determined with ease. As oxygen carriers the perborates are well adapted for converting lower oxides to a higher state of oxidation, ferrous salts being converted into ferric salts, ferric sesquioxide being precipitated from an alkaline solution. Copper oxide and cupric salts are converted into peroxides which immediately decompose with liberation of oxygen. Again, cuprous salts combine with perborates to form insoluble stable salts. The perborates of strontium, calcium, magnesium, barium, and zinc have also been prepared, but their composition varied with the conditions of the experiment.

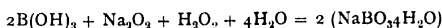
Ammonium Perborate.—Several ammonium perborates have been prepared. One of these, with the formula $\text{NH}_4\text{BO}_3 \cdot \text{H}_2\text{O}$, contains 16.84 of active oxygen.

Sodium Perborates.—These have been most exhaustively examined. Brahat and Dubois prepared salts of varying composition by the electrolysis of a solution of sodium orthoborate or by precipitating with alcohol a solution of sodium borate in hydrogen peroxide. They described a compound $\text{NaBO}_3 \cdot 4\text{H}_2\text{O}$ and also a tri-, bi-, and monohydrate. The latter is very stable and contains 16 per cent of available oxygen. The monohydrated salt is soluble in water up to 25 parts per 1000 at 20°C . (68°F). The solution behaves like free hydro-

gen peroxide, the solubility is increased by boric, tartaric, or citric acid, and the solubility is greater in glycerine. Sodium perborate may be obtained in the anhydrous condition by prolonged drying in vacuo over phosphorous pentoxide. This anhydrous salt is also a very stable one, retaining 17 out of 19.51 per cent of available oxygen after eighteen months' storage.

Jaubert's "Perborax".—In preparing his perborax, Jaubert mixes 238 parts by weight of boric acid with 78 parts of sodium peroxide with addition to the mixture of 2000 parts of water. The solution rapidly deposits a snow-white crystalline flour of the formula $\text{Na}_2\text{B}_4\text{O}_8 \cdot 10\text{H}_2\text{O}$ and containing 4.17 per cent of active oxygen. Perborax is far more soluble than the sodium perborates, 1000 parts of water dissolving 42 parts at 11° C., 71 parts at 22° C., and 138 parts at 32° C. Free hydrogen peroxide is present in solution without adding sulphuric acid. On recrystallization part of the compound is transformed into $\text{NaBO}_3 \cdot 4\text{H}_2\text{O}$, which is also procured from perborax by saturating one-half of its sodium by mineral acid.

In 1906 Jaubert patented a process for the preparation of sodium perborate, $\text{NaBO}_3 \cdot 4\text{H}_2\text{O}$, in which concentrated sulphuric free from arsenic and iron is mixed with water and treated with a mixture of sodium peroxide and pulverized boric acid, the temperature not being allowed to rise above 20° C. (68° F.). After standing for several hours the precipitate is filtered off, washed with cold water and air dried. In another process Jaubert prepares sodium perborate by the action of boric acid and hydrogen peroxide on sodium peroxide, 500 to 600 parts of 30 per cent hydrogen peroxide being mixed with 200 parts of water and 124 parts of pulverized boric acid are well stirred and then 29 parts of powdered sodium peroxide. The temperature should not exceed 20° C. (68° F.) throughout. Sodium perborate formed according to equation



is rapidly deposited as a white crystalline powder, which is filtered off after standing an hour, washed and dried.

Merck's Sodium Perborate, $\text{NaBO}_3 \cdot 4\text{H}_2\text{O}$, forms pure and perfectly white crystals soluble to 25 per cent in water at 20°C ., contains 10 per cent of active oxygen or twice as much as Jaubert's perborax (*vide supra*). Merck's perborate combines the properties of hydrogen peroxide and borax. Dilute acids liberate hydrogen peroxide and concentrated sulphuric acid causes decomposition with liberation of ozone. Oxygen is liberated when the aqueous solution is warmed to 140°F ., or treated with mineral or organic catalysts, ferments, animal tissues, etc.

Sodium perborate is prepared by the Deutsche Gold und Silber Scheidenstalt, Frankfort-on-Main, by running in 1500 parts of sodium peroxide into 3000 parts of water, enough ice being added to prevent any rise in temperature. Flue gases containing CO_2 but free from dust are injected into the solution until all flue alkali is neutralized, excess of CO_2 being harmless. A concentrated solution of metaborate prepared from 1240 parts of boric acid and 240 parts of caustic soda is next added, the deposition of the sodium borate being facilitated by stirring. By adding ice if need be the final temperature of the liquid is prevented from rising above 20°C . (68°F .). Care is also taken that the volume of the liquid is sufficient to maintain all the soda in solution. The precipitated perborate is filtered, washed, and dried as usual. The sodium metaborate may be replaced by an equivalent quantity of borax or other alkali borate.

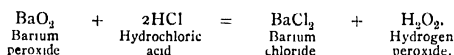
The sodium perborate prepared by the Société d'Oxylithe, Paris, is well adapted for the production of pure hydrogen peroxide. This perborate crystallizes from its aqueous solution at 30°C . (86°F .) as somewhat bulky lustrous prisms. The solution has a decided alkaline reaction and behaves like free hydrogen peroxide in contact with permanganate. Above 40°C . (104°F .) decomposition sets in, oxygen being liberated, but the loss is slight up to 60°C . (140°F .). Between 15° and 32°C . (59° and 89.6°F .) the solubility of the salt is 25.5 to

37·8 grammes per litre ($25\frac{1}{2}$ to $37\frac{3}{4}$ lb. per 100 gallons). By the addition of sulphuric acid, a solution containing over 30 per cent by volume suitable for technical uses can be prepared. By dissolving 170 parts by weight of sodium perborate and adding 60 parts of pure citric acid in 1000 parts of water a 10 per cent solution may be prepared quite as active as ordinary hydrogen peroxide. The bye-products of the decomposition are sodium metaborate or baborate and boric acid and the salt of the acid added, e.g. sodium sulphate or citrate according as sulphuric or citric acid was added. The sodium perborate of the Société d'Oxylithe exhibits the same general properties as that of Brahat and Dubois, $\text{NaBO}_3\text{H}_2\text{O}$, of which 25 grammes dissolve per litre of water at 20°C . (25 lb. per 100 gallons). The hydrogen peroxide solution, made from sodium perborate in virtue of its purity, is specially adapted for bleaching fine delicate goods.

Hydrogen Peroxide, H_2O_2 .—Water, as is well known, consists of hydrogen and oxygen as represented by the formula H_2O . In addition to water, there exists another compound of oxygen and hydrogen (which contains twice as much oxygen as water) called hydrogen peroxide, which was discovered by Thenard in 1818. Hydrogen peroxide is a colourless transparent viscid liquid with a peculiar odour which mixes with water in every proportion and is very readily decomposed. Pure hydrogen peroxide is decomposed even at 15° or 20°C . into oxygen and water. Its solution in water, especially in presence of a little hydrochloric acid, is far more stable. Hydrogen peroxide is best kept in a cool dark place. Stability is better on adding 1 gramme of naphthalene or 20 grammes of alcohol or ether per litre. In alkaline solutions hydrogen peroxide readily parts with its available oxygen.

Preparation. — Hydrogen peroxide cannot be prepared directly from oxygen and hydrogen. It is formed when the oxygen of certain peroxides combines with hydrogen or water. Some peroxides cannot be used to prepare hydrogen peroxide. Barium peroxide, obtained by heating barium oxide in a stream of oxygen, is the most suitable reagent to use, as unlike

manganese peroxide it does not so decompose as to yield water and chlorine, but barium chloride and hydrogen peroxide.



The preparation of pure hydrogen peroxide is a protracted and difficult operation. The barium of the barium chloride is exactly precipitated out of the solution by dilute sulphuric acid, the hydrochloric acid by silver sulphate, whilst the sulphuric acid is exactly precipitated by baryta water so as to obtain a dilute aqueous solution of the substance. A solution of hydrogen peroxide when concentrated by evaporation in vacuo decomposes so much the more readily the more it becomes concentrated. The reactions of hydrogen peroxide are most remarkable. The readiness with which it splits up into nascent oxygen and water causes it to be a highly powerful oxidizing agent for a great number of substances, for sulphurous acid, arsenious acid, and metallic sulphides generally. Black lead sulphide is readily converted by hydrogen peroxide into white lead sulphate, and a practical use is made of this fact to bleach oil paintings, the white lead of which has been gradually converted into lead sulphide and so blackened with age. By cautiously washing with a dilute solution of hydrogen peroxide, the original tints are restored, provided that no other pigment acted on by hydrogen peroxide be present, e.g. madder, lake, etc.

The chemical action of hydrogen peroxide is frequently the reverse of that just described. It then acts as a reducing agent and abstracts oxygen. When an aqueous solution of hydrogen peroxide is added to silver oxide, the liquid froths and evolves much oxygen. The atom of oxygen which the peroxide contains in excess over and above of that required to form water unites with an atom of oxygen from the molecule of silver oxide to form a molecule of oxygen, and the silver oxide is thus reduced to metallic silver by deprivation of oxygen.



Similarly, manganese peroxide MnO_2 is reduced to MnO manganous oxide, and if the solution contains a free acid unites with it to form a manganous salt. This characteristic reaction may be utilized to ascertain roughly whether a greater or less proportion of hydrogen peroxide is present in any given solution. To apply the test, the solution is poured on to a little black oxide of manganese placed in a test tube when oxygen is rapidly evolved in sufficient quantity to rekindle a glowing chip of wood. But to detect mere traces of hydrogen peroxide in an acid aqueous solution a little ether is added and one drop of a solution of potassium bichromate. The mixture is well shaken, after shaking the ether, as it rises to the surface, is tinted a fine blue colour due to some chromium compound more rich in oxygen than chromic acid (CrO_3). It is, however, claimed that titanium sulphate is the most delicate reagent for hydrogen peroxide, as it is said to detect 1 part in 1,800,000 parts of water. When the proportion is 1 in 108,000, the reagent turns dark yellow, and a pale yellowish tint is evident with 1 in 1,800,000.

Manufacture of Hydrogen Peroxide from Barium Peroxide and Hydrofluoric Acid.—According to P. Courey this is the best and the most simple method. (Hydrogen peroxide may, however, be prepared from perborates, persulphates, or percarbonates, but the chief sources are the peroxides of barium and sodium.) The hydrofluoric acid process is as follows. Run 16 gallons of water into a wooden vat along with 30 lb. of hydrofluoric acid and stir into this mixture very gradually about 30 lb. of barium peroxide previously thinned uniformly with 4 gallons of cold water to a creamy consistency. The barium peroxide is best prepared by heating barium nitrate in a current of air to 300°C . (572°F .). Whilst adding this cream to the acid liquid the latter is energetically stirred with a wooden stirrer and not more than 2 lb. of the pulp should be added at a time, since a larger amount or insufficient stirring will cause a sudden rise of temperature with the simultaneous loss of much hydrogen peroxide. The commercial raw materials vary in strength. The proportions given above refer to

concentrated fuming hydrofluoric acid and 85 to 90 per cent barium peroxide. In general the barium peroxide cream is added to the dilute hydrofluoric acid to alkaline reaction, that is, the cream is run into the acid liquid until after ten to fifteen minutes. Vigorous stirring the solution turns red litmus paper blue. Insoluble barium fluoride and hydrogen peroxide are simultaneously formed; the greater the amount of hydrogen peroxide liberated the more gradually is the decomposition process conducted. To ensure perfect decomposition the mixture must be thoroughly well stirred. As soon as the alkaline reaction is observed dilute hydrofluoric acid is added to acid reaction, stirring being continued energetically for half an hour and the mixture left to stand for twelve hours. The barium fluoride subsides and the clear solution of hydrogen peroxide of 10 to 12 (vol.) per cent strength may be drawn off. The deposit of barium fluoride is drained on a filter and afterwards treated with sulphuric acid to recover the hydrofluoric acid for further use. After the complete solution of the peroxide $\frac{3}{4}$ gallon of dilute 40 per cent sulphuric is added to precipitate all the baryta salts as barium sulphate, after which the liquid is neutralized with a solution of 6 lb. 10 oz. of sodium phosphate, oxides of iron and alumina being precipitated, and before filtration the liquid is made alkaline with ammonia so as to neutralize any excess of alkali; the filtrate is run into sufficient dilute sulphuric acid to impart a neutral reaction to the liquid which should contain 10 to 12 per cent by volume of hydrogen peroxide.

Kolbe's Method of Preparing Ozone.—The apparatus consists of a glass cylinder fitted with a wooden lid. Through the centre of this lid there passes a wide glass tube open at the top, closed at the bottom. The lower end of this tube connects with a narrow piece of glass tubing which is melted on to it. This narrow tube is bent upwards and again bent at right angles above the lid. The oxygen enters the apparatus by this tube and leaves it by another, when it is partially converted into ozone. To convert the oxygen into ozone another somewhat smaller tube is placed inside the wide one. This smaller

tube is also open at the top and closed at the bottom and the two tubes are fused together airtight, so that the entering gas passes through the narrow annular space between the two tubes to escape at a certain point. The inner tube and the wide cylinder are filled to about the same height with dilute sulphuric acid, 1 of acid to 10 of water. Into each of these dips a piece of platinum foil to which is melted a piece of stout platinum wire. Both wires are now attached to a powerful induction coil and at the same time dry oxygen is allowed to enter. The two platinum plates and the sulphuric acid with which they are in contact become strongly electrified and discharge themselves silently without the production of sparks through the space between the two tubes by means of which the oxygen is partially converted into ozone.

The construction of the Siemens' ozone tube is on a different principle. It is designed for the preparation of ozone on a comparatively large scale. The apparatus consists of two concentric glass tubes (one within the other) fused to each other at the top. The outer tube is furnished with an inlet tube for the admission of air or oxygen and an outlet tube for the ozonized air or oxygen. The inner tube is lined with tinfoil and the outer tube is covered also with tinfoil, thus forming an electrical condenser, the coatings of which are formed by the tinfoil and the dielectrics by the glass and air. When the tinfoil coatings are coated with rapidly alternating currents of high tension, ozone is formed in and from the adjacent air. Siemens and Halske prepare ozone by the silent-discharge by the use of these tubes which they immerse in water instead of coating them with tinfoil. The water plays the part of the tinfoil.

The Elsworth-Kolle ozone generator, which also acts on the silent-discharge principle of high tension currents, is generated by an alternating dynamo (3-4 amperes and 125-135 volts). The current from the dynamo passes through a specially designed transformer which converts it into an 11,000-12,000 volt current. The silent-discharge field consists of two metallic spirals, one of which is enclosed in a narrow glass tube

and the other in a wider concentric tube surrounding the former. The air or oxygen to be ozonized is passed consecutively through both the inner and the outer tube. The tubes (3-10) are joined up so as to form a battery. With a 10 tube battery 70 grammes of ozone are produced per kilowatt hour. (Later on 125-145 grammes were obtained.) The extent of concentration of the mixture of ozone and air averages 0.4-0.5 gramme per cubic metre, but this concentration may be intensified by joining up a number of apparatus into a battery or series.

Bleaching by Ozone.—Attempts have been made for a long period to bleach textile fabrics by ozone, but till lately without obtaining results which enabled this process to be practically applied. For several years Dr. Fröhlich, in conjunction with Messrs. Keperstein, bleachers of Greiffenberg, has made a special study of this particular question, and the results obtained by them have been such that they have been able to dispense with exposure on the grass, replacing the bleaching action of the green by that of ozone. Bleaching by ozone has been in daily use in the Greiffenberg bleach works for more than a year, and the daily production of linen yarn amounts to 500 kilogrammes of linen yarn daily. Dr. Fröhlich first of all established by his own researches, as well as those of others, that bleaching by ozone alone did not yield good results, because the action of ozone acting by itself alone on linen for the purpose of bleaching is too great, and because the elasticity of the fibres suffers from it. By the ordinary processes linen is bleached by submitting it to the successive actions of soda lyes, chemicks, sours, and exposure on the green, these different operations being carried out and repeated in convenient order. Instead of attempting to bleach by ozone alone, a mixed process has been tried in which the lye-boils, the chemicks, and sours still figure; but exposure on the green is replaced by treatment with ozone. At the outset it was found in bleaching by ozone, just as in bleaching with chlorine, that the bleaching action is at its maximum at the beginning of the process, and if the operation be prolonged beyond measure the bleaching action

is very weak, whilst, on the contrary, the injurious action of the chemicals increases rapidly. There is, therefore, great advantage in using these two agents during a very short time, and to proceed by a succession of feeble treatments. These two decolorizing agents, chlorine and ozone, dovetail into each other in their functions in a really remarkable manner, the one preparing the fibre for the action of the other. Working in this way, favourable results were obtained first in the laboratory, then in a small ozone bleach works installed at Greiffenberg. The process has since been notably improved by moistening the hanks of yarn before treating with ozone with, for example, a weak solution of hydrochloric acid, spirits of turpentine, and ammonia. The chemical reaction which takes place in consequence of the simultaneous action of one of these bodies with the ozone on linen fibres is not exactly known, as the study thereof is very difficult. It has been demonstrated simply that in consequence of the use of one of these substances the bleaching power was increased remarkably, without injuring the goods to be bleached. It is interesting to note that whilst the ozone penetrates into the oil of turpentine, dense white fumes are given off, the chemical action of which is not well known, but which possess a very great decolorizing action. Consequently, in the process described bleaching by ozone replaces bleaching by grass. Between the two there is still this difference. To the action of ozone must be added that of the oxygenated compounds of nitrogen combined with ammonia and of peroxide of hydrogen, and the different compounds act in an extremely weak condition, whilst in bleaching by ozone the latter is employed alone, and in a much more concentrated condition. In the Greiffenberg bleach works the process is used to bleach linen yarn in hanks, and the operation is conducted in the following manner. The hanks undergo the same operations, lye-boils, sours, chemicks, as in the old process, except that exposure on the grass is replaced by spreading in the ozone chamber. The hanks are moistened with one of the substances mentioned above and exposed in the ozone chamber, that is to say, in a space enclosed in

a suitable manner, where they remain exposed to the action of the ozone for six or seven hours. The hanks are then taken out of the chamber, they undergo another feeble process, and when they are dry they are three-quarters white. If a greater white still is required, this is done by a greater number of chemicks alternated with exposures in the ozone chamber. The yarn thus bleached presents, as far as whiteness and elasticity are concerned, all the qualities and appearances of yarn which has been bleached on the green. The cost is appreciably the same, but the great advantage of bleaching by ozone consists in dispensing with bleaching on the grass, by which the bleacher is enabled to accomplish all the operations inside the bleach works, and is able to work as well in winter as in summer. There is also a remarkable economy in time—about a third. The time which the bleaching process will last can also be foretold, so that deliveries may be made within a given time, which formerly was impossible. At Greiffenberg in the ozone chamber the yarn is hung on rods in the same way as in ordinary drying machines.

CHAPTER XV.

CHLORINE AND CHLORIDE OF LIME AND THEIR USE IN BLEACHING.

CHLORINE is a greenish-yellow gas. At the ordinary temperature 1 litre of chlorine weighs 3·17 grammes at 0° C. Its density compared with air is 2·45; its atomic weight is 35·5; its atomic volume is 2. Inhaled in small quantities it produces irritation of the bronchial tubes; inhaled in larger quantities it gives rise to the vomiting of blood. (*Antidote*.—Inhale the vapours of alcohol or ether and drink milk.) Chlorine liquefies at 0° C. under a pressure of 6 atmospheres. Chlorine dissolves in water, yielding chlorine water. The solubility of chlorine in water is very feeble, and its solubility is modified very rapidly by elevation of the temperature.

One litre of water absorbs at—

Degrees C.	Degrees F.	Litres Chlorine.
0 - - - -	32 - - - -	1·430
8 - - - -	46·4 - - - -	3·040
10 - - - -	50 - - - -	3·000
17 - - - -	62·6 - - - -	2·370
35 - - - -	95 - - - -	1·610
50 - - - -	122 - - - -	1·490
100 - - - -	212 - - - -	0·150

When a rapid current of chlorine is made to pass through a condenser it deposits crystals of hydrated chlorine at about 0° C. These crystals may be collected, placed in a tube, the tube sealed, and heated to 38°. Decomposition of the hydrated chlorine takes place and liquid chlorine is obtained under its own pressure.

Chemical Properties.—Chlorine possesses very energetic
(179)

chemical affinities. It combines directly with hydrogen and the metals with disengagement of heat. In sunlight it slowly decomposes water with disengagement of hydrochloric acid. Chlorine eliminates hydrogen from organic matters, and in consequence of this property is used as a disinfectant. It destroys colouring principles. The theory of its action is not very well known, but it is probable that it acts as an oxidizing agent with liberation of oxygen. This oxygen in the nascent state transforms the colouring matter and bleaches it.

Chlorine Water.—Chlorine water obtained by bubbling a current of chlorine through water may be used in bleaching. But this method brings in its train complications and difficulties that the bleacher may obviate by the use of alkaline hypochlorites (*vide infra*) which are endowed with the same decolorizing properties as chlorine itself.

It would seem at first sight that there would be an advantage, from a bleaching point of view, in the use of gaseous chlorine dissolved in water in place of hypochlorites. There are several disadvantages in working in that way. (1) Chlorine gas is but slightly soluble in water and its solution would not stand the cost of carriage. (2) Under the influence of heat and light, chlorine decomposes water and forms hydrochloric acid. It would therefore be necessary to make the chlorine in the bleach works and to make the solution of chlorine as required. This was how they worked in bleach works when they first commenced to use chlorine as a bleaching agent, but this method was given up when the hypochlorites were discovered. (3) Finally, bleaching with chlorine water injures the fabric, because this chlorine passes to the state of hydrochloric acid, which, finding no further base to neutralize, acts in a destructive manner on the fibre.

Chlorine versus Alkaline Hypochlorites.—On the other hand, the alkaline bases have the property of absorbing chlorine and forming with it, very unstable compounds termed hypochlorites, the composition of which is not at all well known. It requires an excess of base to maintain the stability of these hypochlorites. From that fact alone the base in ex-

cess opposes the oxidizing or bleaching action of the chlorine, because it hinders it from being disengaged from its state of combination, and the desideratum is to provide almost neutral hypochlorites for bleaching purposes, that is to say, those which contain but the least possible excess of base. The hypochlorites offer this advantage over chlorine water, that the hydrochloric acid which is formed is soon neutralized by the base of the hypochlorite.

Preparation of Chloride of Lime.—Of all bleaching reagents chloride of lime is by far the most important. Quicklime, which needless to say must be well burnt, is first slaked and then exposed to the action of chlorine gas in layers of 2 or 3 inches in thickness. These layers are laid on perforated shelves in closed chambers made of lead or built of stone flags. The chlorine is injected very gradually so as to avoid too sudden a rise of temperature due to too rapid absorption of chlorine. In fact if the heat rises much higher than 50°C . (122°F .) a certain amount of calcium chloride (CaCl_2) and of calcium chlorate $\text{Ca}(\text{ClO}_3)_2$ are formed, the reaction then being analogous to that occurring during the manufacture of potassium chlorate (KClO_3). Calcium hydrate (slaked lime) (molecular weight 74) may be caused to absorb half its weight of chlorine (37). But calcium hydrate as powder cannot be made to combine with an equivalent of chlorine (CaOCl_2). Bleaching powder always contains lime in excess.

Chloride of Lime in Powder—Properties.—Dry chloride of lime has the same appearance as slaked lime. It ought to be pure white and of a uniform state of division. It has a peculiar odour due to hypochlorous acid, and is a body with altogether different properties to slaked lime. When exposed to the air it *slowly* attracts moisture and becomes deliquescent. Chloride of lime which *rapidly* becomes moist in contact with the air, or is in a milky state as it comes from the casks, ought to be regarded as a deteriorated or badly manufactured article. Beaten up with a small quantity of water it yields a kind of lumpy paste. In a large quantity of water—about fifteen times its own weight—it partially dissolves, leaving a

muddy residue. The dissolved portion only is endowed with bleaching properties. Air, light, increase of temperature partially decompose chloride of lime and reduce its strength. Instances of spontaneous decomposition are quoted where the containing vessels have been shattered by the explosion. This is, however, comparatively rare, and is perhaps due to imperfect manufacture. The manner in which its component elements are combined the one with the other has been the subject of many scientific discussions, which have not resulted in any decided conclusion. One theory is that it consists of hypochlorite of lime ($\text{CaO} \cdot \text{O} \cdot \text{Cl}$), and of chloride of calcium (CaCl_2). It always contains a certain proportion of uncombined or unattacked lime. According to this theory, chloride of lime contains an active chlorine principle endowed with decolorizing properties and an inert chlorine ingredient of no use whatever in bleaching. A second theory—that of Kolb—is that a compound having the formula CaOCl is formed, which is chloride of lime properly so called.

Dissolving Chloride of Lime in Water.—A suitable plant which answers very well for dissolving chloride of lime is shown in Fig. 33 (1). A.—Small tank into which the chloride of lime is dropped and in which it is beaten up with a very small quantity of water by means of a pestle or a mechanical agitator. The orifice is fitted with a metallic sieve so that only chloride of lime in the requisite state of fine division may pass through. The lumps, grit, etc., are beaten up afresh. B.—Oval tank to receive the chloride of lime made into a pasty condition in the vessel A. This paste is diluted with water in the tank B; the proportion generally used is 120 to 150 gallons for 100 lb. of chloride of lime. Mixture is effected by putting in motion two mechanical agitators working in contrary directions for about four hours, after which the whole is left to settle during the night, and in the morning the liquid is drawn off into the tank C. The mud deposited at the bottom retains liquid chloride; it is washed with water, putting the agitators in motion. It is then allowed to settle and the liquid is used to treat the next batch of chloride of lime, and

the residual mud transferred to the rubbish heap. If thought desirable the deposit may be washed a second time. The clear liquid to be used in bleaching is syphoned off and the

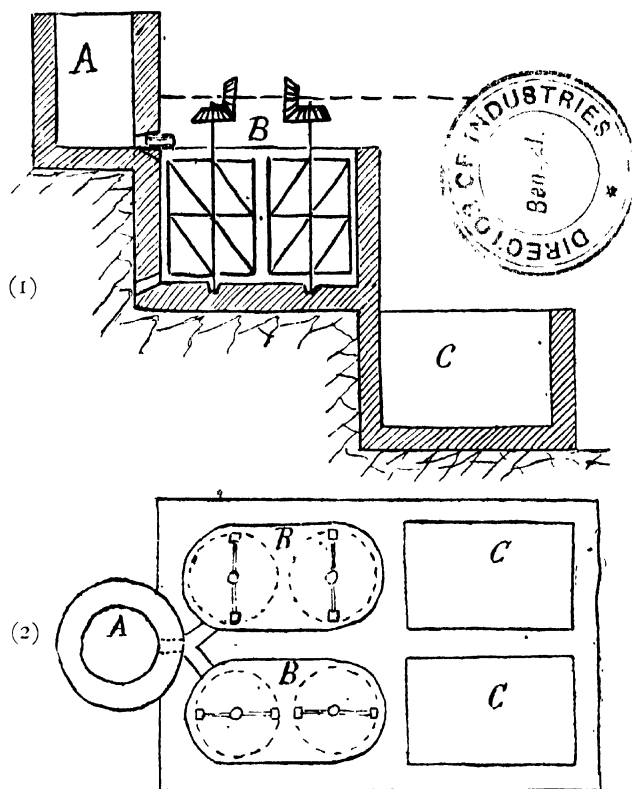


FIG. 33.—Plant for dissolving bleaching powder in water.

wash water pumped back. As will be seen, the operation is very simple. The only point to be observed is that care must be taken to see that all the lumps are well broken up. In many bleach works the chloride of lime is simply run into the tank B, and beaten up with the agitators. The author

recommends the tank A for breaking up the chloride, because chloride of lime in lumps dissolves with difficulty, and mere agitation with water is not sufficient. It cannot be too strongly recommended to take especial care in the decanting or syphoning off, so that only the perfectly clear liquid be used. Almost all the mishaps that occur in the use of chloride of lime arise from the fact of its having had lime in suspension, and it needs only a very small quantity of lime to injure the material to be bleached.

Weisbach's Dissolving Plant.—The above method is that most usually adopted in France. The firm of Ch. Weisbach of Chemnitz manufacture a special dissolving plant, which is preferable. This plant is used to mix the chloride of lime and water, whilst at the same time the lumps dissolve better. It consists of a wooden tank lined with lead, with a tap for running in the water and another for the discharge of the liquid chloride, and a hole in the bottom (closed by a plug when at work) for washing out the residue. Inside is a sheet-iron drum lined with lead and zinc laid lengthwise in the tank. This drum is pierced with small holes and is furnished with a hinged lid for the introduction of the chloride of lime. The drum is mounted on a shaft carrying pulleys, outside the tank, to receive the driving strap or belt that imparts the rotatory movement to the drum. The tap for running off the liquid chloride is fixed some distance from the bottom, so that none of the mud is run off with the liquid.

Liquid Chloride of Lime.—Chloride of lime in powder is very convenient for transport, but it always contains a large excess of lime. When chloride of lime is exhausted with water there remains in suspension an abundant, white precipitate, which is nothing more nor less than calcium hydrate (slaked lime). If this solution be allowed to stand the lime falls to the bottom, and a clear greenish-yellow liquid is obtained containing hypochlorite of lime and calcium of chloride. If, instead of allowing the solution to deposit the lime, a current of chlorine be passed through it in the cold, the lime in suspension gradually dissolves and a perfectly clear liquid is,

obtained. The liquor then contains nothing but hypochlorite of lime and calcium chloride. From the point of view of utilizing the lime the liquid chloride is the more rational, and it is the more easy to prepare.

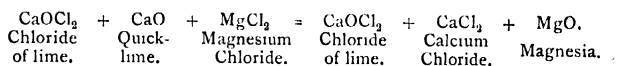
Preparation.—Milk of lime is placed in a carboy, or in a covered vat and a current of chlorine passed through. In order to avoid pressure the current of chlorine is led to the surface of the bath and the liquid set in motion by an agitator. Care is taken not to exceed a temperature of 30° to 35° C. at the most, so as not to decompose the chloride, which would yield chlorate. The operation should be stopped before all the lime is dissolved so as to avoid decomposition. The liquid, after clarifying, should not have a greater gravity than 17° Baumé. Between 13° and 15° is the general limit. One hundred and fifty pounds of chloride of lime are used for 100 gallons of water, and 10 lb. of lime are left undissolved. Sometimes a little chlorate is obtained owing to the temperature of the bath being allowed to rise too high, or because too much lime has been dissolved. When the process is finished the chloride is drawn off, allowed to settle, and the clear liquid syphoned off.

Lunge's Process for Increasing the Intensity of the Bleaching Power of Chloride of Lime.—Professor Lunge uses an agent not formerly employed, viz. a feeble acid such as formic acid or acetic acid. The price of the acetic acid is not an obstacle, because only small quantities are required, and because this acid, being constantly regenerated, may be used for a long time. The acetic acid, in presence of chloride of lime, yields free hypochlorous acid and acetate of lime. During the process of bleaching the hydrochloric acid reacts on the acetate of lime, yielding chloride of calcium; the acetic acid is again liberated and the reaction is renewed a second time. The hydrochloric acid which is formed in the process of bleaching never remains in the free state, because it reacts on the acetate of lime, liberating acetic acid. This fact is of great importance, because hydrochloric acid reacts in an injurious manner on the fibre if it remain in contact with it for too long a time,

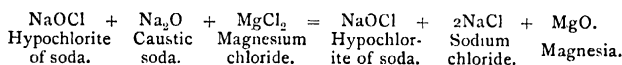
whilst it is well known that acetic acid is quite harmless. As there is no formation of insoluble salts of lime, the souring operations which immediately succeed the chemick may be dispensed with; under these circumstances there is not only a decided economy, but, moreover, there is no danger of leaving a mineral acid on the fibre in consequence of imperfect washing and the damage to the fibres attendant thereon, which is more especially to be feared in the case of thick fabrics. Acetic acid may be used in different ways, either by adding it to the chemick, or by passing the fabrics through a weak sour after the ordinary chemick, or moreover, by passing the fabrics through water slightly acidulated with acetic acid in which chloride of lime is introduced gradually. It is asserted that if the process be well conducted there is every safety in the use of chloride of lime, with the advantage that it is not necessary to dirty so much water. If any lye remains in the fabrics, or if the water be hard, or if the chemick contain caustic lime in excess, a larger quantity of acetic acid is required to neutralize the bases in the first place before liberating the hypochlorous acid. In this case it is economical to neutralize the free alkali or the lime by sulphuric or hydrochloric acid, and then to add the necessary quantity of acetic acid to produce the reaction.

Tailfer's Process for Removing the Excess of Lime or Soda from Bleaching Powder, etc.—In order that the hypochlorites of lime and soda may be employed under the most favourable conditions for bleaching they should be neutral, that is to say, the hypochlorite of lime should not contain an excess of lime, nor the hypochlorite of soda an excess of soda; because lime or soda in excess retards the bleaching capacity, and, what is more serious, lime acts injuriously on the textile fabrics. But, on the other hand, it is absolutely necessary that bleaching powders contain an excess of lime or soda to enable them to be preserved, otherwise they would decompose very rapidly. Generally, in order to remove the excess of lime or soda, resource is had to acids, sulphuric acid or hydrochloric acid, more rarely acetic acid. The two first, being very

strong acids, violently attack the hypochlorites, and it is difficult in the actual practice of a bleach works to estimate the quantity of acid to use to remove the excess of base—lime or soda—alone, without attacking the hypochlorite. Now if the hypochlorite be attacked there is a rapid disengagement of chlorine which attacks the textile fibres very energetically, and there is great reason to fear their being damaged. Acetic acid would be preferable, but its high price hinders its industrial use in connection with bleaching powder. By the author's process the excess of lime or soda of the hypochlorites of lime or soda are removed, and that without decomposing the bleaching powder which is left in a neutral state. In order to do this, magnesium chloride is made to react on the hypochlorite of lime or soda. With chloride of lime the reaction is as follows:—



The magnesia, which is insoluble, is precipitated, the chloride of calcium remains in solution, and the hypochlorite properly so called is not attacked by the chloride of magnesia, even employed in excess. If, instead of chloride of lime, chloride of soda (eau de Javelle, chlorozone, chlorogene, etc.) be acted on, the reaction is as follows:—

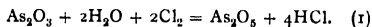


The chloride of sodium remains in solution, the magnesia is precipitated, and the hypochlorite of soda is left untouched. The magnesium chloride may be used in the following manner. (1) The chloride of lime is run off clear; it generally indicates 7° to 10° Baumé, and it is strongly alkaline. To neutralize it magnesium chloride is added in sufficient quantity to transform the lime (CaO) in excess into chloride of calcium (CaCl₂), which remains in solution. The magnesia is allowed to settle and the clear liquid drawn off. (2) When hypochlorite of soda is being treated the process is conducted

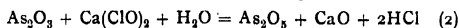
in the same way, whatever may be the strength of the hypochlorite. The quantity of magnesium chloride to use is determined according to the excess of soda contained in the hypochlorite. (3) Instead of treating concentrated solutions of chloride of lime or hypochlorite of soda with magnesium chloride the operation may be performed on the chemicks, that is, on the concentrated solutions diluted with water, so as to bring them to the strength at which they are to be used for bleaching purposes. Magnesium chloride is added to destroy the excess of base, whether lime or soda, and the chemick is conducted in the usual way. No fear need be entertained in regard to the precipitate of magnesia; it has no effect on the substances to be bleached, and is removed by washing. It is easy to prove by a rapid experiment the advantages which may be gained by this process. With this end, in view, two chemicks, for example, are made with hypochlorite of soda or eau de Javelle of the same strength. To the one a little chloride of magnesium is added to destroy the soda in excess, and the other chemick is left to do its work in the ordinary way. A swath of the same textile fabric is steeped in each chemick, and as the bleaching proceeds the following observations are made. (1) The fabric steeped in the chemick to which the chloride of magnesium was added bleaches more rapidly than the fabric plunged in the ordinary chemick. (2) The fabric, even though left much longer in the ordinary chemick, does not become so white as that which was steeped in the chemick to which the chloride of magnesium was added. (3) The strength of the fabric placed in the chemick to which the chloride of magnesium was added is not inferior to the strength of the textile chemicked in the ordinary way. Magnesium chloride, used in conjunction with chloride of lime, increases the activity of the bleaching power, but, above all, it removes the excess of lime, changing it into calcium chloride, and it prevents the very injurious action of lime on textile fabrics, an action well known to all bleachers. This injurious action of lime is so much feared that many bleachers have given up the use of chloride of lime, substitut-

ing for it hypochlorite of soda, which is three times more costly, but does not contain lime. By the judicious employment of Tailfer's process, chloride of lime may be used with as much safety as hypochlorite of soda. Bleachers who use hypochlorite of soda, eau de Javelle, or others, will find an appreciable advantage in the addition of chloride of magnesium to neutralize it by removing the excess of soda which retards the bleaching power of the decolorizing chloride. Very often the fabrics or yarns are not washed when they come out of the lye. The bleacher simply lets them drain and in this condition chemicks them. This is a saving of labour; moreover, the goods to be bleached are still warm and in a spongy condition favourable to the penetration of the chemick; but, on the other hand, the soda lye which they retain is opposed to the action of the chemick by diminishing its bleaching power. By taking care to previously add magnesium chloride to the chemick, the chloride of magnesia destroys the soda in excess; the magnesia resulting from the reaction has no injurious effect on the fabrics and is removed by washing.

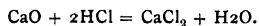
The Light Thrown by Analysis on the Constitution of Bleaching Powder.—The method of estimating chlorine due to Gay-Lussac is based on the following reaction:—



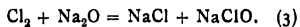
That is to say, two molecules of chlorine transform one equivalent of arsenious acid into arsenic acid. This formula cannot be established otherwise if it be a question of chlorine water, but if hypochlorites of the form Ca_2ClO are being estimated the reaction can also be explained as follows:—



and as secondary reaction:—

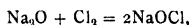


When chlorine is passed into soda lye the text-books of chemistry indicate the following reaction as the result:—

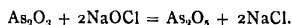


If the hypochlorite thus formed be estimated with arsenious acid almost all the chlorine absorbed by the soda is found as

hypochlorite. Now, according to the formula, only half that quantity ought to be so found when titrated with arsenious acid, because chlorine in the state of chloride of sodium does not oxidize arsenious acid. To explain, therefore, how the whole of the chlorine is found as hypochlorite there is occasion to suppose that something analogous to what is indicated in formula (2) takes place. It has been said that almost the whole of the chlorine is found as hypochlorite, because there is always a small quantity which passes to the state of chlorate or chloride. Chemists do not agree as to the nature of the compounds formed by the combination of chlorine with the alkalis. Kolb assigns a combination which would have the formula NaOCl , and it is this latter opinion which appears to be the most capable of explaining the different phenomena observed in connection with hypochlorites. According to this hypothesis the reaction of chlorine upon soda is expressed by the following equation:—



and the reaction with arsenious acid would be:—

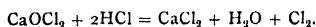


Rapidity of Action of the Bleaching Energy of Hypochlorites.

—The point which interests the bleacher is to know to what the greater or less activity is to be attributed. Now there would appear to be no doubt but that it depends on the greater or less excess of base present in the hypochlorite. When chlorine is estimated by arsenious acid, hydrochloric acid is always added to neutralize the excess of base and to disengage the chlorine from its combination. Take several samples of the same hypochlorite and render the first slightly acid, the second neutral, the third alkaline, and gradually increase the alkalinity of the samples. If we titrate them with arsenious acid without the addition of hydrochloric acid, it will be seen that the chlorometric strength goes on diminishing in proportion as the alkalinity increases. This proves that alkali, in excess, diminishes the oxidizing power of the hypochlorite. On the other hand, if we preserve the samples it will be seen that

those which were acid or neutral decompose very quickly, and that the others keep longer without decomposing the greater amount of the quantity of alkali in excess which they contain. It follows, therefore, in making hypochlorites that they should contain the excess of base necessary to preserve their stability, but no more, as that would retard their bleaching action.

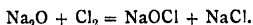
Hypothesis as to the Composition of Bleaching Powder.—The common opinion is that this is a body the formula of which would be Cl-Ca-O-Cl . Kolb gave it the formula CaOCl_2 , and in connection with titration with arsenious acid reasons are given why this explanation would appear to be the most satisfactory. Tailfer believes it necessary to consider chloride of lime as a body in which the following substances may be present. (1) Chlorine A: chlorine loosely combined with lime. (2) Chlorine B: chlorine in the free state, which would be simply absorbed or dissolved by the lime. (3) Chlorine C: chlorine combined with lime in such a stable manner that it has no decolorizing power whatever, such as calcium chloride, CaCl_2 , or chlorates. (4) Lime in excess amounting to about 35 per cent in solid chlorides, and in liquid chlorides a quantity of lime corresponding to its coefficient of solubility in hypochlorites. This explains the slow decomposition of chloride of lime. In fact, free chlorine in presence of water, heat, and light decomposes water, and transforms it into hydrochloric acid. This hydrochloric acid, in its turn, acts on hypochlorite of lime, and sets a fresh quantity of chlorine at liberty.



This free chlorine retransforms itself into hydrochloric acid, decomposes a fresh quantity of chloride of lime, and so on. Once the decomposition of the chloride has got a fair start it goes on very rapidly. That explains why an excess of lime is required to give stability to the chloride. The lime in excess reduces the bleaching power of chloride of lime as compared with hypochlorite, the soda of which is far more soluble in water than the lime in bleaching powder.

Hypochlorite of Soda.—When a current of chlorine is passed into a solution of soda, chlorine is absorbed with evo-

lution of heat, and a greenish-yellow liquid results. Works on chemistry give the following reaction :—



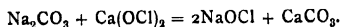
There is thus formed one equivalent of hypochlorite of soda and one equivalent of sodium chloride. There may, however, be grounds for admitting that there is formed a compound having the formula NaOCl , as Kolb has indicated for "chloride" of lime, CaOCl .

If care be not taken to always maintain an excess of soda, and that the point of saturation be not passed, the chloride decomposes very rapidly with disengagement of gas bubbles.

Thus a solution commencing to decompose fell in an hour from 20 chlorometric degrees to 2 chlorometric degrees.

Different Methods of Producing (Sodium Hypochlorite).—The use of hypochlorite presents great advantages in bleaching, more especially as far as safety is concerned. As this substance only exists in the liquid state dissolved in a large quantity of water, its transport is costly; different methods of preparing it in bleach works will therefore be explained.

Preparation of Sodium Hypochlorites by the Reaction of Carbonate of Soda on Chloride of Lime.—The principle of the reaction is the following. When a sodium salt reacts on "chloride" of lime, hypochlorite of soda is formed, and the corresponding lime salt is precipitated. For example, if carbonate of soda be used a solution of hypochlorite of soda results, with precipitation of carbonate of lime according to the following equation :—



Proportions.—In order to find the quantity of carbonate of soda required to transform 100 lb. of chloride of lime into hypochlorite of soda, the following calculation is made.

Example.—One hundred kilogrammes of chloride of lime, testing 102 chlorometric degrees, react according to the definition of the chlorometric degree as if they contained 100 kilogrammes $\times 102^\circ = 10,200$ litres of available chlorine, or a weight of chlorine equal to $10,200 \times 0.00317$ kilogrammes. In fact a litre 0.00317 kilogramme represents the weight of a

litre of gaseous chlorine at 0°C . The equivalent of chlorine Cl_2 is 71, and whatever be the manner in which it is combined with lime it requires one equivalent of pure dry carbonate of soda, 106, to each equivalent of chlorine to convert into the sodium salt. The following proportion gives the weight P of carbonate of soda required to convert 100 parts of chloride of lime into sodium hypochlorite:—

$$\frac{P}{32.334} = \frac{106}{71} = \frac{106 \times 32.334}{71} = 48.3 \text{ kilogrammes.}$$

To make sure that no lime remains this quantity must be increased to neutralize the excess of chloride of lime dissolved in the chloride of lime. A good proportion to use is 55 lb. of soda ash (Brunner Mond's) for 100 lb. of chloride of lime. The quantity of water to effect solution depends on the strength required. Actual practice shows that it is undesirable to exceed 8 to 9 chlorometric degrees. The quantity of water X will therefore be

$$X \times 8 = 100 \text{ kilogrammes} \times 102^{\circ} X = \frac{10,200}{8} = 1,275 \text{ litres or } 280\frac{1}{2} \text{ gals.}$$

Description and Arrangement of Plant.—The illustration (Fig. 34) shows a very convenient arrangement for the preparation of sodium hypochlorite. The tanks are of mason work lined with cement and at different levels. On the top layer an agitator with blades mechanically mixes the chloride of lime and water. The work of the agitator may be replaced by that of a man who beats up the chloride of lime with a wooden pestle or chopper. The important thing is not to leave any lumps. When the chloride of lime is well beaten up, it should be run into the lower tank, through a metallic sieve, thus ensuring that the whole has been reduced to a suitable state of division. The solutions are run from one tank into another by means of syphons. The wash water is pumped up to the top tank, to be used in the exhausting of a fresh quantity of chloride of lime. To make 900 to 1000 litres (198 to 220 gallons) of 8 chlorometric degrees the process is conducted as follows. Dissolve in a tank 55 kilogrammes (121 lb.) of carbonate of soda. In winter it is advisable to

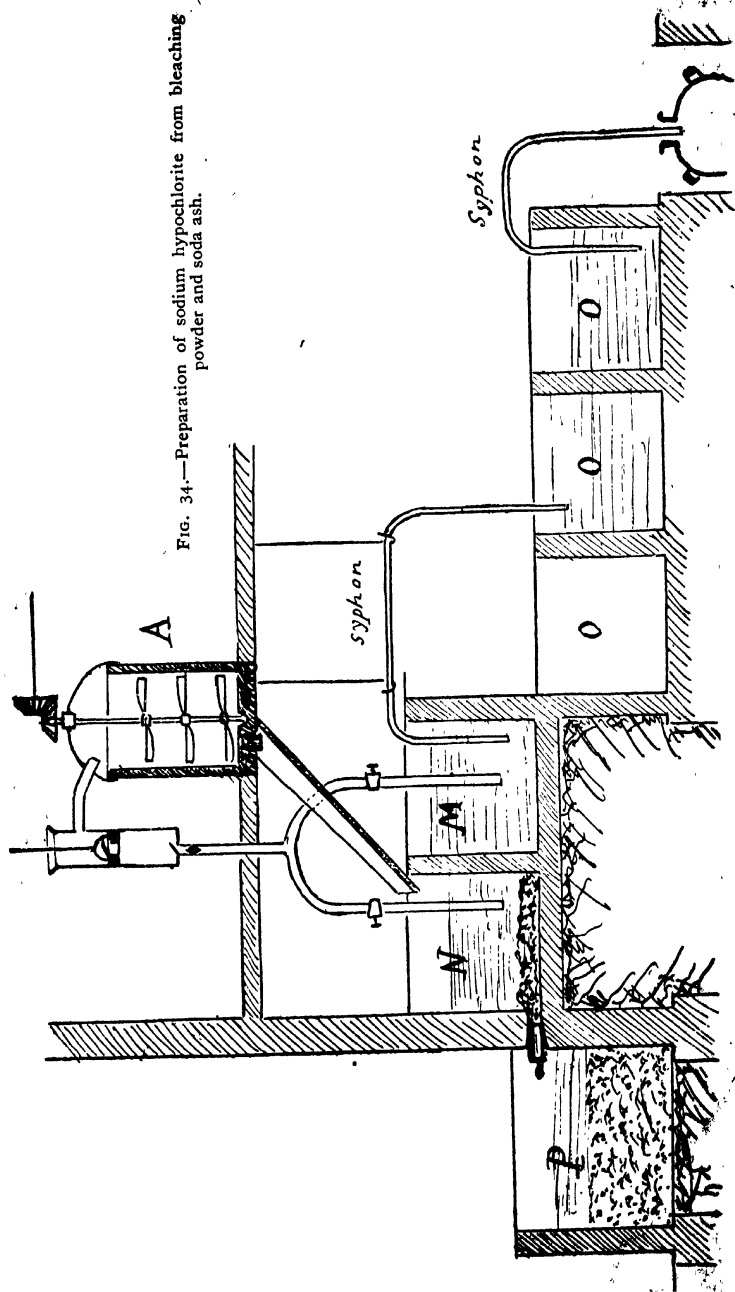


FIG. 34.—Preparation of sodium hypochlorite from bleaching powder and soda ash.

use tepid water. Run in gradually into the mixer 100 kilogrammes (220 lb.) of chloride of lime which is beaten up with the wash water of previous operations taken from the vat N by the pump. After the 100 kilogrammes (220 lb.) of chloride of lime have been run in, keep the mixer going for two hours and then run the solution into the vat M in which the carbonate of soda has been previously dissolved. Tilt the vat to the desired height so as to have 1·275 litres with the wash waters of the vat N and mix the whole well. Let stand till morning and with a syphon run the clear liquid into one of the vats O. Wash the deposit in the vat M and allow to stand. The clear liquid is used to exhaust the chloride of lime of the next operation. The residue is then run into a rubbish receiver P. Allow the liquids in the tank O to stand until the morning and then syphon off into carboys, being careful only to run off the clear liquid.

Testing.—The chlorometric strength or degree is estimated by one or other of the different methods of titration used in chlorometry. If the resulting products do not correspond with the strength aimed at the cause for this defect must be found. To ascertain whether enough carbonate of soda has been used a sample of the clear solution is taken and a few drops of carbonate of soda are added. If there be a precipitate there is unattacked lime remaining in excess, and enough carbonate of soda has not been used. It is desirable that there should always be carbonate of soda in excess, but in small quantity, because in the first place it is a useless expense of carbonate of soda, and secondly because too great an excess of carbonate of soda reduces the bleaching power of the chloride of soda. How to estimate the amount of alkali in excess is described in chapter XIV.

Preparation of Sodium Hypochlorite by the Action of Caustic Soda on Chloride of Lime.—When it is desired to make sodium hypochlorite of high strength, that is to say of about 30 chlorometric degrees, caustic soda must be used instead of carbonate of soda.

Proportions.—The calculation of the quantity of caustic

soda required to transform a known weight of chloride of lime is analogous to that given for the carbonate. Supposing it is desired to transform 100 kilogrammes of chloride of lime 102° chlorometric strength into hypochlorite of soda. These 100 kilogrammes of chloride of lime contain

$$100 \text{ kilogrammes} \times 102^\circ \times 0.00317 \text{ kilogramme} = 32.334.$$

Now the equivalent of chlorine is 71, that of soda is 62, hence the weight X of soda required to combine with 32.334 kilogrammes of chlorine is given by the following calculation :—

$$\frac{X}{32.334} = \frac{62}{71} \quad X = \frac{62 \times 32.334}{71} = 28.23 \text{ kilogrammes.}$$

These 28.23 kilogrammes represent anhydrous sodium oxide Na_2O . Commercial caustic soda always contains water and other impurities. This soda is sold according to the Descroizilles degree; by multiplying the Descroizilles degree by 0.632 the percentage of anhydrous soda is obtained. Supposing caustic soda testing 110° Descroizilles is being used, this soda contains $110 \times 0.632 = 69$ per cent of soda Na_2O . The weight 28.23 kilogrammes must be increased in the ratio of $\frac{100}{69}$ thus, $\frac{28.23}{69}$ kilogrammes $\times 100 = 41$ kilogrammes of

soda of 100° Descroizilles. To produce sodium hypochlorite of 8 to 9 chlorometric degrees the carbonate of soda process may be followed, but if a high strength be desired recourse must be had to a process of successive enrichment and methodical exhaustion of the residual mud.

Process.—The arrangement of the plant is the same as that shown in Fig. 34, but four or five reagent tanks are used instead of two. The caustic soda of 110° Descroizilles is dissolved in a cast-iron vessel in the ratio of 330 lb. per 100 gallons of water. The charge of chloride of lime is run into the mixer and dissolved in the liquid pumped from the tanks, a liquid already enriched with hypochlorite of soda by methodical washings. There is placed in the tank where the reaction occurs the quantity of caustic soda solution required to convert the chloride of lime (beaten up with the washings

in the mixer) into sodium hypochlorite, and the required volume is made up with washings from a neighbouring vat. The whole is then agitated very energetically and then decanted, and the clear liquid, consisting of strong sodium hypochlorite, is syphoned off. The methods of manufacture established in the other tanks or vats contain respectively a liquid which diminishes in richness in chloride of soda from one vat to the other. To exhaust the muds methodically the clear liquid from each vat is run into the succeeding one so that it is enriched in contact with muds richer in hypochlorite of soda. The vat containing the poorest mud is filled with water; this done, all the vats are stirred energetically and allowed to stand. Decantation over, the liquids are run from one vat into the next. The mud of the last vat, sufficiently exhausted, is thrown away, and it is this vat which is free for the reaction of the next batch of chloride of lime and caustic soda. The quantities of chloride of lime and caustic soda and the volume of liquid to use depend on the degree of concentration desired in the hypochlorite of soda. The calculation of this is easy, as shown above. This plant and method are not suitable for obtaining a greater strength than 30 to 33 chlorometric degrees.

Preparation of Sodium Hypochlorite by the Action of Sulphate of Soda on Chloride of Lime.—In order to convert chloride of lime into sodium hypochlorite, sulphate of soda may be used in place of the carbonate; insoluble sulphate of lime is formed. The advantage consists in the low price of sulphate of soda, less than £1 per ton. This is war time and even sulphate of soda is dear, but let the pre-war argument stand. Low-priced sulphate of soda contains many impurities and the resulting sodium hypochlorite is more or less impure. The forcing of crude impure acid sulphate of soda on users of sulphuric acid is a minor war-time hardship, the more so as it is a poor substitute for the pure acid. Sulphate of lime deposits badly; to aid decomposition a mixture of carbonate and sulphate of soda is used. The carbonate of lime carries down the sulphate of lime in its train and the liquid clarifies much

more rapidly. The calculation of the quantity of sulphate of soda required to convert a given weight of chloride of lime into chloride of soda is made in a manner analogous to that indicated for carbonate of soda or caustic soda. It is evident that the percentage of anhydrous sulphate Na_2SO_4 , equivalent 142, in the sulphate must be known. The plant is the same as that already described.

Brochoki's Chlorozone.—Brochoki put on the market some thirty years ago a hypochlorite of soda chlorozone obtained at a regulated cold temperature by saturating a solution of caustic soda of a greater or less degree of concentration by a current of chlorine, which he says is previously peroxidized. It is a clear limpid liquid, producing neither deposit nor formation of crystals at the bottom of vessels in which it is contained. At the density of 1.385 it is said to acquire a decolorizing power of above 120 chlorometric degrees, and exposed in this condition to a temperature of 1°C . it crystallizes in mass in beautiful rhomboidal bright yellow crystals. Chlorozone is marketed at a density of $1.258^\circ (50^\circ\text{Tw.})$. It then contains

	Per Cent.
Chlorine - - - - -	12.68
Oxygen - - - - -	5.82
Sodium - - - - -	8.62
Water of combination - - - - -	3.38
Water of solution and other substances - - - - -	69.50
	<hr/> 100.00 <hr/>

At this density 1 litre of chlorozone tests 50 chlorometric degrees, i.e. 50 litres of chlorine per litre. The chlorozone made in the chemical works of Kuhlman of Lille has a density varying from 1.18 to 1.20. It tests 35° chlorometric, i.e. equivalent to 35 litres of chlorine per litre. Tailfer used chlorozone for four years in a bleach works of fine linen and cotton fabrics, and as a result of his experience he is able to say of this product that it may be used by bleachers with the greatest elements of safety or sense of security from injury being done to the fabrics. He has used it both in the hot and the cold, and its use has always been attended with the same excellent results.

This product runs from 14 to 18 francs (5s. 6d. to 7s. the cwt.) the 100 kilogrammes, on account of the cost of carriage. Weight for weight it contains three times less chlorine than chloride of lime. Its relatively high price is accounted for by the fact that it is not very extensively used.

Researches on Chlorozone by Professor Mills, D.Sc., F.R.S.—

It will be interesting to quote here what Professor Mills has said about chlorozone, not only as showing what may be done with this product, but more especially to point out what conception one ought to have of the products due to the absorption of chlorine by alkalies, and also what advantage may be obtained by the use of chlorine in the hot state:—

“Our knowledge of the oxygenated compounds of chlorine is so far from being complete that we cannot say with precision what chlorozone is, or to what series of reactions it owes its origin. At first sight one would be led to suppose that this product would be a hypochlorite of soda (*eau de Javelle*), in other words, that it would be identical with the product obtained by treating a solution of chloride of lime with carbonate or sulphate of soda. The supposition can be easily decided by experiment. If solutions of chlorozone and hypochlorite of soda of equal density and chlorometric strength produce the same effect on colouring principles they are identical, if not they are different. A piece of stuff dyed with Turkey red was steeped in a sample of chlorozone, of density 1.0686°, and this bath brought slowly to the boil; the colour was bleached in three minutes. A similar experiment with hypochlorite of soda produced only partial bleaching after very prolonged boiling. Chlorozone and hypochlorite of soda are not therefore identical. But it is right to say that highly concentrated chlorozone kept for a long time would not probably produce the same results as obtained by the bleaching of the stuff dyed with Turkey red. A dilute solution of chlorozone preserves its properties much longer. I have never known exceptions. Moreover, the peculiar smell and the yellowish colour of chlorozone are altogether different from those of solutions of hypochlorite of soda of the same density

and chlorometric strength. The process of the preparation of chlorozone is such that chlorine or a more or less oxygenated compound of chlorine is produced which is absorbed, perhaps not too intimately, by the caustic soda. Finally it seems probable that chlorozone is essentially a hypochlorite of soda more or less charged with chloric peroxide and perhaps with lower acids. If this be so an analogous compound would be a solution easily prepared of caustic soda alkaline to turmeric paper but containing free iodine in solution. The use of chlorozone is very simple. The goods, sometimes after an alkaline lye-boil, are steeped in a solution of chlorozone more or less strong and left until the desired effect is obtained. If heat must be used it is applied to the bath and its contents, but after having kept it for some time at the ordinary temperature. It need not be heated above 60° C. (140° F.) except to economize time, because chlorozone is very active at 50° to 60° (122° to 140° F.). Or again, the cloth is soured, washed as usual, and sometimes the operation is repeated on the same goods. There is reason to believe that sunlight assists the bleaching action of chlorozone. Bleaching by chlorozone is generally done in the following solutions: (1) Bath A. 1.5 chlorometric degrees; (2) Bath B. 3.0 chlorometric degrees. More dilute solutions may be used for less important work; for example, 0.3 to 0.5 chlorometric degree. The above and following details are not given in order that they should be adopted in their entirety but to serve as a guide to those who use chlorozone. In operations on a large scale more dilute solutions than those given will answer perfectly well. Where the sample is caustic a little bicarbonate of soda is the best agent to apply."

Cotton Bleaching by Chlorozone.—Mills bleached a piece of cotton perfectly thus: The coarse fabric, boiled for an hour in a solution of soda crystals (1 in 100), wrung and washed, was plunged in a bath of chlorozone A for two and a half hours at 62° C. (143.6° F.), then again wrung and soured with HCl for an hour. The fabric was again washed, etc., and plunged in a second bath A at 60° C. (140° F.) for three hours,

then wrung, soured, washed, and dried. The result was quite equal to the average obtained by the processes so long in use. The duration of the process was about nine hours. The greater part of this loss of time was due to the lye-boiling.

Yarn Bleaching.—As regards yarn, chlorozone may be used in the ordinary manner as a substitute for chloride of lime. The following are the details of the operation. Boil your yarn in lye, and allow to cool during the night as usual. Wash and wring. Prepare then a bath of 100 volumes of water at about 95° C., add thereto 10 volumes of ozone or weak chlorozone, rinse (this bath will test about 0.4 chlorometric degree), and agitate rapidly. Plunge the goods therein, and allow to cool for an hour and stir from time to time. Withdraw, wring and acidulate for an hour. Result: a brilliant white.

Linen Bleaching.—Mills bleached linen the most brilliant white in the following manner. He prepared a chemick diluted to the strength A, and immersed the linen therein in the cold. The effect was produced in about an hour. At the end of three hours he heated the bath and its contents to 54° C. during an hour, took out the linen, rinsed it, passed it through acid, and rinsed it. Four hours sufficed for this operation. To make certain whether a better result still might not be obtained, the linen was immersed again in bath A for five hours in the cold, and one hour at 55° C.; the operation finished, but little difference was observed after the second treatment. The total loss was 16.2 per cent. During these operations the linen took up a little organic chlorine, the greater portion of which is probably introduced at the time it passes through the acid. Any antichlor, such as sulphite or hyposulphite of soda, ammonia, etc., will remedy this drawback.

Bleaching of Sheetting.—An excellent white may be obtained in the following way. Heat the unbleached sheetting to 100° C. for an hour in a solution of soda crystals (1 in 100), wash in water. Pass to the bath A, leave for two and a half to three hours in the cold; heat the bath and its contents to 50° C. for an hour; take out the sheetting and rinse it. The final opera-

tion consists in passing through acid as usual, hydrochloric acid being better than sulphuric. The sheeting is washed, passed through another chemick, soured, and washed. In a special experiment the loss of weight was 1.37 per cent, which is insignificant; the sheeting is not shrunk and does not lose any of its textile strength. The operation lasts less than nine hours. It is probable that in many cases the boiling with dilute alkaline lye may be suppressed, at least as far as cotton is concerned. Three-quarters white, second quality, may be obtained by a single heating for two hours at 70° C. in a bath of chlorozone of 1 volume to 120 volumes of water. The sheeting, as in ordinary bleaching, takes up a little organic chlorine. The bleaching process may be conducted in many cases in the following manner. Prepare bath A, steep the cloth therein for three hours at the ordinary temperature. A visible effect will be produced in half an hour: take out the cloth, squeeze, wash, and dry. Some yellow spots may be formed, which will disappear during drying. The stuff will become whiter after several days, and if there be no great pressure of work, a second chemick, followed by washing and drying, will be very advantageous.

Various Hypochlorites. *Hypochlorite of Potash.* — This chloride is obtained in the same way as hypochlorite of soda and it has analogous properties. It is more rarely used, as potash is dearer than soda and now unattainable.

Hypochlorite of Magnesia. — This is obtained by the action of sulphate of magnesia (Epsom salts) on "chloride" of lime. This product is almost neutral; its bleaching power is very active. The solidity of the fabric is as well preserved as with chloride of lime or soda. Hypochlorite of magnesia decomposes very quickly. Tailfer has prepared it of eight chlorometric degrees and in two days it had run down to 2°. Decomposition went on afterwards but more slowly.

Hypochlorite of Zinc. — Prepared by the action of sulphate of zinc on chloride of lime. The bleaching power is very energetic, but the durability of the goods to be bleached is more effected than with alkaline hypochlorites.

Costellé's Hypochlorite.—Tailfer some years ago made a particular examination of a hypochlorite of soda made by Costellé at Pontherry, Seine et Marne, France. This hypochlorite of soda is produced by the action of sulphate of soda on chloride of lime. It is sold on the market at 33° to 35° chlorometric strength and has a density of 23° by Baumé's hydrometer. The method of manufacture is a trade secret. This product, being almost neutral and containing not a trace of either caustic or carbonated alkali, is highly esteemed for the bleaching of coloured fabrics, the colour of which is attacked by alkalies whether caustic soda or carbonate of soda. This product is employed in bleaching silk where the ordinary hypochlorites could not be used. Commercial sulphate of soda, now a glut in the market, can be readily purified to make an excellent hypochlorite.

Comparison of Chloride of Lime and Hypochlorite of Soda from the point of view of Economy, Safety, and Bleaching Power. *Economy.*—From an economical point of view chloride of lime is the cheapest. In fact the price of chloride of lime varies in different countries between 8s. and 10s. the cwt. Taking chloride of lime at 100° chlorometric, the price of the litre of chlorine will be for chloride of lime at 25 francs per 100 kilogrammes (10s. the cwt.)—

$$\frac{25}{100^{\circ} \times 100} = 0.0025 \text{ francs [0.024d.]};$$

for chloride of lime at 17 francs the 100 kilogrammes—

$$\frac{17}{100^{\circ} \times 100} \text{ kilogrammes} = 0.0017 \text{ francs [0.016d.]}. \quad .$$

This price must be increased 10 per cent to make allowance for the chlorine carried away in the residue. The price of hypochlorite of soda of 30 chlorometric degrees may be estimated at 12 francs the 100 kilogrammes in Belgium (say 5s. the cwt.); at 15 francs the 100 kilogrammes (6s. the cwt.) in the N. and E. of France; 18 francs (7s. 2d.) in the W. and S. The price of the litre of chlorine from hypochlorite of soda runs therefore in Belgium 0.004 francs; in France N. and E. 0.005 francs;

in France W. and S. 0'006 francs. Let the pre-war prices and the arguments based on them stand. The present high prices merely accentuate the argument. The chlorine from the chloride of lime is thus cheaper, and on this account is preferably employed in the bleaching of the larger numbered yarns and common sheeting. It has the disadvantage of being injurious to the workmen beating it up with water and of leaving a residue which is often very cumbrous. The hypochlorite of soda being sent out in carboys there is no necessity to exhaust it before use. But as it is a liquid product which does not often contain more than 30 litres of chlorine per kilogramme, it is more difficult and more costly to transport than chloride of lime in powder, which contains at least 100 litres of chlorine per kilogramme.

Safety.—Chloride of lime (solution) ought to be perfectly clear before being used. If this precaution does not receive the attention which it deserves, and should it contain lime in suspension, even in small quantity, the fabrics are seriously damaged. Moreover, even clear liquid chloride of lime always contains a little lime in solution, and this lime exerts an injurious action on the fabric. Hypochlorite of soda, on the other hand, has soda for its base—a perfectly soluble substance which has not the injurious action on fabrics which lime has. Experience has proved that fabrics treated with chloride of soda preserve their durability better. When it is a case of bleaching fine fabrics, the author believes that there can be no question of hesitancy or doubt, and that hypochlorite of soda ought to be preferred. The difference in price will be more than compensated by safety in use and the better preservation of the bleached fabric. In the case of common fabrics, the remuneration for bleaching which is hardly profitable, it must be left to the bleacher to decide for himself, making sure that he can rely on his staff, and that only perfectly clear chloride of lime be used. In factories where hydraulic power is available, it would be of great profit to use electrolytic sodium hypochlorite, for in that case its price is lower than chloride of lime.

Bleaching Power.—The more easily the hypochlorites are

decomposed, the more active they are, and, on the other hand, this decomposition takes place the more rapidly the hypochlorite approaches the neutral state. To this may be attributed the difference which exists in the rapidity of action of chloride of lime and hypochlorite of soda. Clear liquid chloride of lime only contains in solution a small quantity of free lime, which corresponds to the feeble solubility of lime in the chloride.

Hypochlorite sodium, on the other hand, contains free soda in very variable and sometimes considerable proportions. Chloride of lime acts therefore more energetically than hypochlorite of soda, but both of these may be reduced to a state of equal activity by neutralizing by an acid the base in solution. But this must be done with caution, as the acid first neutralizes the free bases and then decomposes the hypochlorite with liberation of chlorine. It is sometimes advantageous to diminish the bleaching action of hypochlorite of soda, as for example, in the treating of fabrics containing coloured patterns which it is desired to preserve. Carbonate of soda is then added to the liquid to render it alkaline, or better still, bicarbonate of soda, which transforms caustic soda into carbonate of soda.

A general idea has already been given in previous paragraphs of the nature of chlorine and its compounds, its bleaching action, and the properties of the different hypochlorites, their mode of production, and the methods used to determine their strength. They may be summarized as follows. The accepted opinion is that chlorine, in bleaching, oxidizes the colouring principles of the fabrics, and the oxygen so liberated combines with hydrogen to form hydrochloric acid. The chemicks ought to be weak enough and to last for such a short time as only to attack the colouring principle and not the fabric itself by converting its cellulose into oxycellulose or into hydrocellulose. The bleaching reagents most usually employed are chloride of lime and hypochlorite of sodium. When chloride of lime is used care must be taken to see that the liquid is perfectly clear and that all the

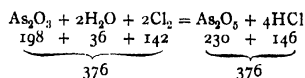
lime has settled out well. If any lime remains in suspension the fabrics will be damaged. Hypochlorite of soda is higher in price than chloride of lime, but it is more safe and does not impair the strength of the fabrics to the same extent. It is used for fine goods. The hypochlorites are easily decomposable substances, especially when neutral; an excess of alkali imparts stability to them. In the neutral state their bleaching power is very energetic, but its action is moderated by an excess of alkali. It is not advisable to use hypochlorite solutions, the bleaching power of which is too energetic, because the chlorine would only bleach the surface of the yarn without penetrating into the interior. It is also to be feared that it might attack not only the colouring principle, but also the fibre itself. On the other hand, the hypochlorite must not, in consequence of an excess of alkali, be too slow in bleaching, because the fabrics would run the risk of being destroyed by remaining too long in the chemick. In the case of clear liquid chloride of lime, the excess of lime is almost constant and corresponds to the small amount of lime soluble in the chloride. But as regards hypochlorite of soda, the excess of soda, on account of its great solubility, may be very considerable. Experience has proved that the hypochlorite of soda most suitable for bleaching should only contain a small excess of soda. A chloride of 15° chlorometric strength ought to contain 3 to 4 grammes per litre of caustic soda NaHO in excess. The chlorometric degrees used to indicate the strength of the chemicks are French chlorometric degrees. They express the number of litres or fractions of litres of gaseous chlorine contained in one litre of chemick. The methods of treating or testing the strength of the chemicks are indicated. Some bleachers still rest satisfied with taking the gravity of the chemicks with a hydrometer. Hydrometers only indicate the density of the solutions, and not the chlorometric strength. As the chlorometric strength and density do not always correspond, this mode of testing should be abolished, as it only yields but very coarse approximations and occasions mistakes of great damage to the fabrics.

Chlorometric Degree.—The chlorometric degree of chloride of lime varies between 100 and 110 degrees. That means that 1 kilogramme of chloride of lime can decolorize or bleach to the same extent as 100 to 110 litres of dry gaseous chlorine reduced to 0° C., and measured at the atmospheric pressure. As far as liquid hypochlorites are concerned, the chlorometric degree is an index of the number of litres of active chlorine contained in a litre of liquid chloride. As an example, when it is said that Brochoki's chlorozone tests 35 chlorometric degrees, that signifies that a litre of chlorozone contains 35 litres of active or available chlorine. When any one speaks of a chemick of 1 or 2 chlorometric degrees, what is meant is that that chemick contains 1 or 2 litres of active chlorine per litre. In France the chlorometric degree of *solid* hypochlorites refers to the *weight*, and the chlorometric strength of *liquid* hypochlorites refers to the *volume*. The English or German degree indicates the *weight* of active chlorine contained in the chloride. Therefore, N English or German degrees = M French degrees $\times 3.17$ grammes, 3.17 grammes being the weight of a litre of chlorine at 0° C. at the normal pressure.

N.B.—Chlorine exists in two different states in chlorinated bleaching agents and hypochlorites generally. One part of the chlorine exists in such a state of combination that it plays the same part, as far as its bleaching properties are concerned, as gaseous chlorine dissolved in water. This is active chlorine. Another portion of the chlorine is combined in such a manner as to be useless for bleaching purposes. This is inert chlorine. Thus in liquid hypochlorite of soda there is present not only hypochlorite of soda, the chlorine of which possesses bleaching properties, but also chloride of sodium or sea salt, the chlorine of which has no action. Volumetric or titration methods only give the available chlorine. These methods are based on the oxidizing strength of the chlorine, and the results obtained show that the samples in question have the same oxidizing value or the same bleaching properties as a certain number of litres of chlorine. But it is quite possible that it is not the chlorine alone which produces this oxidation of the oxygenated bodies; the

oxygen of the hypochlorite may also oxidize directly, and this is the reason why it is *not* said that a hypochlorite of any given chlorometric degree contains so many litres of active chlorine, but only that its decolorizing or bleaching properties have the same effect as so many litres of active chlorine.

Titration by Arsenious Acid.—This method, due to Gay-Lussac, is based on the following reaction :—



that is to say, that two equivalents of chlorine 2Cl_2 transform one equivalent of arsenious acid into one equivalent of arsenic acid. Now a litre of chlorine weighs 3.17 grammes. If, therefore, it be desired to ascertain the weight of arsenious acid which will be converted into arsenic acid by 3.17 grammes of chlorine, the necessary data is afforded by the following proportion sum :—

$$\frac{3.17 \text{ gr.}}{142 (2\text{Cl}_2)} = \frac{\text{X}}{198 (\text{As}_2\text{O}_3)} = \frac{3.17 \times 198}{142} = 4.42 \text{ As}_2\text{O}_3.$$

That is to say, that to convert 4.42 of arsenious acid into arsenic acid it requires 3.17 grammes, or, in other words, 1 litre weight of chlorine.

Preparation of the Standard Arsenious or Chlorometric Solution.—Vitreous arsenious acid ought to be pulverized whilst warm, and cooled out of contact with a moist atmosphere; 4.42 grammes of arsenious acid are weighed, then dissolved in a solution containing 150 cubic centimetres of hydrochloric acid and 150 cubic centimetres of distilled water, and the whole heated for four or five hours to 40°C. on the water-bath. After solution and cooling, make up to a litre with distilled water. This solution is then standardized so that to transform 1 cubic centimetre of arsenious into arsenic acid it requires 1 cubic centimetre of chlorine.

Saturation Point.—To know at what moment all the arsenious acid is converted into arsenic acid, 10 cubic centimetres are drawn off and a few drops of sulphindigotic acid are added

thereto; the chlorine first of all transforms the arsenious acid into arsenic acid, then a drop in excess decolorizes the sulphindigotic acid. This shows that the reaction is complete.

Method of Titration.—Ten cubic centimetres of the arsenious acid solution are run into a test glass and tinted blue with sulphate of indigo, and the chlorinated liquid is added from a burette until complete decoloration is effected and the solution so adjusted that 10 cubic centimetres of the arsenious acid solution equals 10 cubic centimetres of available or active chlorine. Supposing then, for example, that 6 cubic centimetres of the liquid chloride are required to give the chlorometric degree, the following proportion sum results :—

$$\frac{X}{10 \text{ c.c. chlorine}} = \frac{1 \text{ litre}}{6 \text{ c.c. chlorinated liquid}}$$

$$X = \frac{10}{6} = 1.66 \text{ chlorometric degrees;}$$

or, in other words, there is 1 litre 66 cubic centimetres of chlorine per litre in the chlorinated solution tested. If a burette be divided into cubic centimetres and tenths of cubic centimetres, it is necessary each time to calculate this proportion sum. But in the special chlorometric burettes this proportion sum is calculated beforehand, in fact the chlorometric strength is indicated on each division of the burette. Where it is desired to use a burette graduated in cubic centimetres, the following table will give the chlorometric strength corresponding to the number of cubic centimetres run in. *N.B.*—The addition of hydrochloric acid to the solution of arsenious acid is absolutely necessary to liberate the chlorine from its state of combination, otherwise only one portion of the chlorine would come into play. The volume of arsenious acid is taken as the constant volume and not that of the chemick to be tested, because the hydrochloric acid contained in the arsenious acid might disengage more chlorine than the arsenious acid would absorb and the gaseous chlorine liberated would escape titration.

COLUMN A.—NUMBER OF CUBIC CENTIMETRES OF NORMAL CHLOROMETRIC SOLUTION RUN INTO 10 CUBIC CENTIMETRES OF THE CHEMICK TO BE TESTED.

COLUMN B.—CORRESPONDING CHLOROMETRIC DEGREE.

A	B	A	B	A	B
1	10	8.5	1.17	31	0.32
1.2	8.3	9	1.11	32	0.31
1.4	7.1	9.5	1.05	33	0.30
1.6	6.6	10	1	34	0.29
1.8	5.5	11	0.91	35	0.28
2	5	12	0.83	36	0.27
2.2	4.5	13	0.77	37	0.27
2.4	4.2	14	0.71	38	0.26
2.6	3.8	15	0.66	39	0.25
2.8	3.5	16	0.62	40	0.25
3	3.3	17	0.58	42	0.24
3.2	3.1	18	0.55	44	0.23
3.4	2.9	19	0.52	46	0.22
3.6	2.7	20	0.50	48	0.21
3.8	2.6	21	0.48	50	0.20
4	2.5	22	0.45	55	0.18
4.5	2.2	23	0.43	60	0.17
5	2	24	0.42	65	0.15
5.5	1.82	25	0.40	70	0.14
6	1.66	26	0.38	75	0.13
6.5	1.53	27	0.37	80	0.12
7	1.43	28	0.35	90	0.11
7.5	1.33	29	0.34	100	0.10
8	1.25	30	0.33		

The chlorometric burette is convenient for the titration of chlorinated liquids, the strength of which varies between 2.0 and 0.4 chlorometric degrees. If a stronger liquid is being dealt with, there will be much less of the standard solution to be run in, and a small error in reading will cause a considerable error in the valuation of the chlorometric strength. If the chlorinated liquid tests below 0.4 chlorometric degree, a large volume of the standard solution must be run in; this, besides being troublesome, will dilute the arsenious solution so much that it will be difficult to catch the commencement of the bleaching of the indigo. In the first case it is advisable to dilute the chlorinated liquid with water, in a known proportion, so as to bring it between 1 and 2 chlorometric degrees. The

test is made and the result is multiplied by the rate of dilution. In the second instance easier results may be obtained by R. Wagner's method for titration of weak chemicks detailed further on. Sulphate of indigo is not completely decolorized by chlorine; it first assumes a greenish tint with violet reflections, and then becomes yellow, and it is the transitional state from green to yellow which indicates the point at which to stop. This stopping-point requires an experienced eye to catch it, and with gaslight it is still more difficult. In commercial analyses sulphindigotic acid has been displaced by Poirier's orange. A few drops of Poirier's orange colour the 10 cubic centimetres of standard arsenious acid a rose colour, and as soon as the chlorinated liquid has oxidized the arsenious acid into arsenic acid it decolorizes a further drop of Poirier's orange. The reaction is very distinct even in gaslight.

Titration of Chloride of Lime in Powder.—Chloride of lime in powder generally tests between 90 and 120 chlorometric degrees. Ten grammes of the chloride of lime to be tested are weighed into a mortar, a little water added, and the whole beaten with a pestle so that no lumps remain; then this paste is made up with water to 1 litre. The whole is well mixed and allowed to stand until a clear liquid is obtained. The chlorometric burette is filled to 0° with this liquid. Ten cubic centimetres of the standard arsenious acid are run into a beaker and coloured by one or two drops of sulphate of indigo; then the chlorinated liquid is run in from the burette, drop by drop, stirring with a glass rod. The reaction is finished when the bluish-green colour of the indigo has disappeared. The reading of the burette gives the chlorometric degree, whether it be read directly from the burette or found by means of a table. If the chloride of lime tested 120 chlorometric degrees, for example, in making the test just described the result found will be 120 chlorometric degrees; that is to say, in the 10 grammes of chloride tested there would be 12 litre of chlorine, and in a kilogramme, or 1000 grammes, there is 100 times more, or 120 litres of chlorine. The chlorometric degree is therefore 120.

Titration of Liquid Chloride of Lime.—When chloride of lime is beaten up with water there is obtained a liquid chloride of lime which tests generally 7 to 10 chlorometric degrees. In making the test direct only 1 or 2 cubic centimetres would be required to be run in, hence a small error in the reading would lead to a considerable error in the estimated strength. It is advisable, therefore, to take 100 cubic centimetres of the liquid chloride to be tested, and to dilute with water to form a litre, and to make the test on this dilute solution. The result is multiplied by 10 to obtain the chlorometric strength of the original chloride. The hypochlorite of soda made in bleach works, of 7 to 10 chlorometric degrees, may be tested in the same manner.

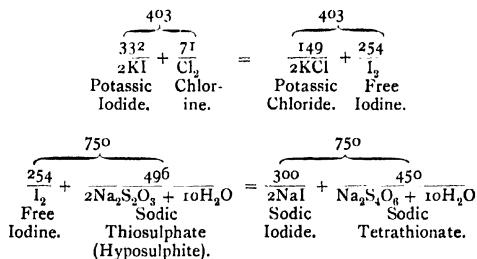
Titration of Brochoki's Chlorozone (35 chlorometric degrees).—Fifty cubic centimetres of the chlorozone are diluted with water to 1 litre, the test is made on this diluted solution, and the result multiplied by 20 to obtain the chlorometric degree of the chlorozone.

Valuation of the Strength of the Chemicks used in Bleaching.—In bleach works where the chemicks are not heated the strength of the chemicks varies between 0.40 and 3 chlorometric degrees. The chlorometric burette is therefore filled directly with the liquid to be tested, the test performed as indicated, and the reading of the burette or the table will give the chlorometric strength. When the chemicks are heated they are used more dilute, say 0.15 to 0.70 chlorometric degree. To ascertain their strength it is advisable to use Wagner's method, by which the $\frac{1}{160}$ part of a chlorometric degree may be estimated.

Wagner's Chlorometric Method.—The chlorometric method of Wagner is based on the decomposition of the iodide of potassium by chlorine in a hydrochloric acid solution. The iodine is liberated in proportional weight to that of the chlorine. The liberated iodine is estimated by hyposulphite of soda, which dissolves it as colourless iodide of sodium, with formation of a tetrathionate or salt of the thionic series. The iodine liberated by the chlorine communicates a yellow colour to the

liquid, and the hyposulphite of soda, by converting the iodine into iodide of potassium, causes this coloration to completely disappear. It is very easy to catch the point at which the reaction is complete.

The reactions take place according to the following equations :—



It follows from these equations that one equivalent of chlorine (35.5) liberates one equivalent of iodine (127), and that this equivalent of iodine is converted into iodide of potassium by one equivalent of hyposulphite of soda (248). The quantity of hyposulphite of soda, X, corresponding to 1 litre of chlorine is arrived at as follows :—

$$\frac{X}{248} = \frac{3.17}{35.5} X = 22.1 \text{ grammes.}$$

Preparation of Standard Solutions. Sodium Hyposulphite.

—22.1 grammes of hyposulphite of soda are dissolved in distilled water and made up to a litre. Each cubic centimetre of this solution is equivalent to 1 cubic centimetre of gaseous chlorine.

Potassium Iodide.—The potassium iodide is dissolved in an unknown quantity of water. A good proportion is to dissolve 100 grammes of potassium iodide in a half litre flask, and to preserve this solution in a blue or yellow bottle, because light decomposes iodide of potassium. One cubic centimetre of this solution contains a little more iodine than 10 cubic centimetres of chlorine can liberate. The following proportion gives the

weight X of iodide of potassium, the iodine of which is liberated by 3.17 grammes of chlorine, or 1 litre:—

$$\frac{X}{166 \text{ (KI)}} = \frac{3.17 \text{ grammes}}{35.5 \text{ Cl}} X = 14.8 \text{ grammes.}$$

It follows, therefore, that 1 cubic centimetre of a solution of iodide of potassium made in the proportion of 148 grammes per litre contains the quantity of iodine that can be liberated by 10 cubic centimetres of gaseous chlorine.

Hydrochloric Acid.—The chemick to be tested is acidulated with hydrochloric acid. The pure strong acid should not be used, as the action would be too violent and the iodine would be precipitated in crystals. One part of hydrochloric acid, 22° Baumé, is diluted with 3 parts of water.

Titration of a Chemick.—Ten cubic centimetres of the chemick to be tested are run into a glass, then the potassium iodide is added, and two drops of hydrochloric acid added to liberate the chlorine. The chemick then takes a yellow tint. A burette divided into cubic centimetres and tenths of cubic centimetres is then filled to 0° with the sodium thiosulphate, which is then run in until the brown coloration completely disappears. The number of tenths of cubic centimetres used indicates the hundredths of the chlorometric degree. For instance, if 35 tenths of a cubic centimetre, or 35 small divisions be used, that indicates that the chemick is 0.35° chlorometric. Generally a 10 cubic centimetre burette is used for running in the sodium thiosulphate. So as to avoid having to fill it several times, the liquid to be titrated should be diluted so as not to exceed 1° chlorometric. In general, chemicks for textile fabrics do not exceed this strength, and are titrated directly. If the chemick be of 2° to 3° chlorometric, as is the case for yarn, it is diluted with water to double or triple its volume, and the result found by titration multiplied by 2 or 3, as the case may be. In the case of solutions of chloride of lime testing 8° to 10° chlorometric, 100 cubic centimetres are drawn off and diluted to 1 litre, titrated, and the result multiplied by 10. Brochoki's chlorozone tests 35° chlorometric.

Ten cubic centimetres are taken and diluted with water to 1 litre, the solution titrated, and the result multiplied by 100.

N.B.—It is necessary to run in enough potassium iodide to liberate all the chlorine in the chemick to be tested. A cubic centimetre of potassium iodide prepared as above is added for every chlorometric degree, but it is always better to add too much than too little. In the latter case the titration will give erroneous results, as there will not be enough iodine to liberate all the chlorine.

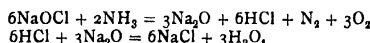
It is sufficient to run in two or three drops of hydrochloric acid to disengage the chlorine. Pure (concentrated) hydrochloric acid should not be used, because the chlorine is disengaged too quickly, does not remain in solution in the liquid, and precipitates the iodine in black crystals. Moreover, sodium thiosulphate dissolves this iodine with greater difficulty, and thereby renders the titration liable to errors. This also occurs when a too highly concentrated bath is titrated. It is better to recommence the experiment by adding water to the vessel after running in the 10 cubic centimetres of the liquid to be titrated.

Apparatus Used in Chlorometry.—By whatever method the chlorometric strength is determined the apparatus used should comprise the following. (1) A mortar and pestle to crush the chloride of lime to be tested. (2) Litre flask with mark. (3) A cylindrical glass jar of 500 cubic centimetres or 1000 cubic centimetres divided into decilitres and centilitres. (4) Several test glasses and stirring rods. (5) One 100 cubic centimetre pipette, one 10 cubic centimetre pipette without divisions, and another 10 cubic centimetre pipette divided into cubic centimetres. (6) One 10 cubic centimetre burette divided into cubic centimetres and tenths of cubic centimetres. Another burette of 25 cubic centimetres divided into cubic centimetre and tenths of cubic centimetres. (7) A litre of standard arsenious acid or normal chlorometric solution. (8) A bottle of sulphindigotic acid. (9) A litre of sodium thiosulphate, 22.1 grammes per litre. (10) Half litre of a solution of potassium iodide—200

grammes to the litre—which is kept in a yellow or blue glass bottle. (11) A bottle of dilute hydrochloric acid.

Excess of Alkali in Bleaching Agents.—It is useful to know the excess of alkali in bleaching agents, especially the soda in excess in sodium hypochlorite, because on this quantity of soda depends the stability of the chloride and the activity of its bleaching power.

The following is one method used. Ammonia is added to the sodium hypochlorite, which converts the chlorine into hydrochloric acid, and this hydrochloric acid converts the chloride of soda into sodium chloride, reactions represented by the following equations:—



It must be observed that the soda only of the sodium hypochlorite of soda is transformed into sodium chloride by the ammonia, and that the soda in excess is not attacked. The solution is then boiled to expel ammonia. Water is added to make up the original volume, and the soda in excess is determined by titration.

Bleaching by Chloride of Lime. Chemick Tanks.—The chemick tanks are constructed of wood if to be used with weak chemicks. Generally they are of masonry lined with cement.

Wooden Cisterns or Troughs.—The vats have a round or square form. They are provided with a false wooden bottom. This false bottom is formed of wooden laths at a certain distance from each other, and fixed to cross pieces or by boards joined together and pierced with holes. The vat is emptied by a hole made in the side in the well between the bottom and the false bottom. It is closed in the easiest way by a wooden spigot. Cisterns are rarely made with a diameter greater than 2 or 2½ metres (say 6½ to 8 feet). If required of greater capacity, they are made of a rectangular shape.

Cisterns Constructed of Masonry.—Masonry cisterns are rectangular in form; it is advantageous to have several of them arranged consecutively. The well underneath the false bottom communicates by a cast-iron pipe with a centrifugal pump, which

re-delivers the liquid into any one of the cisterns, where it flows into perforated wooden troughs or trays above the cistern, and so percolates through the cloth into the well underneath, to be again pumped up, and this cycle of operations continued during two or three hours. Working in this way, when a chemick has acted for the necessary time, the liquid is drawn off by the pump, and transferred to another tank, where it is kept in reserve. The chemick is replaced by water, and the fabrics may thus remain without danger until it is convenient to wash them. By running the water on to the top of them for a considerable time, a first washing is given to the fabrics in the chemick cistern ; but this is not sufficient, it has to be followed by washing in the machines. The fabrics are placed in the chemick cisterns by the aid of delivery rollers and reels. A special reel is used to draw the fabrics from the one side of the cistern to the other during the progress of the chemick ; the operation is termed reeling. By this excellent process the chemick is made to thoroughly penetrate every portion of the fabrics and at the same time to expose them whilst impregnated with chlorine to the action of the air, which still further stimulates the bleaching. A speed of 3000 to 4000 metres an hour answers very well. A man stows them with a stick on the side on which they fall back. For washing purposes the reels are arranged in such a manner that the pieces are drawn from the chemick cistern by the washing machine. If the fabrics are to be collected in packets or bundles to be afterwards washed with the dash wheel or the stocks, the rollers may deliver them at a speed of 5000 metres (say 3 miles) per hour for light fabrics, and 3000 metres (say $1\frac{1}{4}$ mile) for heavy goods. Cotton goods, more easily bleached than linen, rarely require reeling. In this case it is advisable to use the pump to circulate the chemick by drawing it from the bottom of the cistern and re-delivering it on to the surface. The chemick, being constantly on the move and forced to pass through the fabrics, penetrates them better.

Chemicking.—Different Methods. Stowing with the Feet.—Round wooden vats, the diameter of which does not exceed

1 to 1·2 metre, are to be preferred. The chemick is prepared of the desired strength and temperature, and is well stirred so as to mix it thoroughly; then the fabrics in parcels are thrown in after slackening the cord which binds them. A man shod with india-rubber boots mounts on the top of them and stamps them down until they are well immersed and have no further tendency to reascend. If the strength of the chemick be weak (0·30° chlorometric strength at the maximum) and the temperature about 25° C., the man who stows them does so barefooted and barelegged; this enables him to work with greater freedom. The chemicking process being at an end, the chemick is run away or collected in another cistern, water is run on the fabrics, and they are withdrawn to be conveyed to the washing machines. This method of stowing is only suitable for light fabrics, and there are but few causes of damage to be feared.

Stowing with a Stick.—The chemick being prepared in the cistern and stirred, a winch delivers the fabrics and a man immerses them in the bath with a stick as they arrive. This method of stowing is very good, because the chemick penetrates well throughout the entire fabric.

Stowing in the Dry.—When fabrics of a spongy texture are to be chemicked, such as dry piqués or swanskin piqués (piqués secs ou molletonnés), they are stowed in the chemick cistern as they come from the lye-boil keir, after having been washed in the latter by a current of water which still leaves them lukewarm. They are kept down by wooden cross pieces, a pump causes the chemick prepared in another tank to flow on to the top, and withdrawing it from the bottom circulates it through the fabrics. This circulation ought to go on for at least two hours. The advantage of this method of working is the ability to place a great weight of fabrics in a comparatively small space, but it is necessary to stow the goods very regularly, and the fabrics should be of such spongy a nature as to be easily penetrated by the chemick. This method of working is not to be recommended for linen fabrics. The attempts made by Tailfer yielded bad results.

He employed it with success in the case of cotton fabrics such as piqués, ribbons. The fabrics were simply washed in the lye-boiling keir, and not by the machine; they were still hot and in a condition which favoured the penetration of the chemick. Any lye which they might still retain has only the effect of slightly retarding the action of the chemick. The chemicks given did not exceed 0.35° chlorometric strength. In the beginning the temperature of the chemick in contact with the fabrics rose to 35° C., then, as the effect of circulation, cooled to 25° C.

Chemicking in the Washing Machine.—Certain cotton fabrics, such as spongy goods, light calicoes, etc., are chemicked by passing the pieces into a washing machine containing chemick. The chemick is renewed as fast as it is absorbed. As the fabrics issue from the washing machine they are piled on a wooden board, where they remain about three hours; during this time the chemick continues to act upon them. Care must be taken that no portion dries whilst impregnated with chemick. The fabrics are then washed in the washing machine, and soured in the usual way.

Reeling.—As already indicated, this operation consists in passing the fabrics by the aid of rollers from the one side of the chemicking trough to the other. The object is to thoroughly impregnate the fabrics with chemick, and, by moving them through the liquor, to cause the chemick to penetrate as far as possible into the interior of the fibres. This operation is almost indispensable for tightly woven linen fabrics, especially if tightly packed in chemicking troughs. Cotton fabrics are not in general reeled; they are more easily bleached than linen fabrics. A man is required to immerse the fabrics with a stick as the reel brings them from the other side of the trough. The expense in labour is largely compensated by the better white. The operation of reeling is more especially useful in the first and second chemick.

Strength, Temperature, and Duration of Chemicks.—In the examples of bleaching processes (chapter XII.) the degrees, temperatures, and duration of chemicks which are indicated

have been most successfully employed in actual practice. Some general ideas will therefore only be given here. When chloride of lime is used it is not advisable to heat it. This bleaching agent is used in the bleaching of linen and hempen yarn and coarse sheeting of the same materials. Yarns from No. 0 to No. 16 are treated with chemick of 2.5° chlorometric strength; from No. 16 to No. 30, 1.5° to 2° ; from No. 30 to No. 50, 1.0° to 1.5° . Above No. 50 the strength should not exceed 1° . The steep lasts from 1 to $1\frac{1}{2}$ hour. Many bleachers employ chloride of lime for coarse sheeting, because it costs less than sodium hypochlorite.

The strength of the chemick and duration of the steep:—

Order of Chemick.	Strength in Chlorometric Degrees.	Duration.
1st Chemick - -	0.8 to 1.0	3 hours
2nd Chemick - -	0.6 to 0.8	3 hours
3rd Chemick - -	0.3 to 0.4	3 hours

In summer, the temperature of the chemicking liquor being higher, the strength must be diminished from one to two-tenths of the degree indicated in the table. In winter it must be increased in a similar ratio. The table is constructed for an average temperature of 15° C. (60° F.). For fine linen and cotton fabrics it is advisable to use hypochlorite sodium; greater security and soundness in the fabrics more than compensates for the increased expenditure.

The Temperature of the Chemicks.—The temperature of the hypochlorite of soda chemicks may be increased without danger to 25° C. (77° F.). They then acquire a much more energetic bleaching action. The following examples show the difference in the action between hot and cold chemicks.

1. *Chemicking for Piqués Secs and Swanskin Piqués, Cotton Ribbons, etc.*—*Hot Chemick.*—Sodium hypochlorite heated to 25° C. (77° F.) used on fabrics coming from lye-boil, washed in the keir, and not by the machine.

Order of Chemick.	Strength in Chlorometric Degrees.	Duration.
1st Chemick - -	0'35	6 hours
2nd Chemick - -	0'25	6 hours
3rd Chemick - -	0'15	4 hours

Cold Chemick.—Sodium hypochlorite at a temperature of 12° to 15° C. (53·6 to 59° F.), acting on the same kind of fabrics, having been washed in the washing machine after being lye-boiled.

Order of Chemick.	Strength in Chlorometric Degrees.	Duration.
1st Chemick - -	0'95	3 hours
2nd Chemick - -	0'90	3 hours
3rd Chemick - -	0'60	3 hours

2. *Chemicking of Fine Linen and Muslins.*—*Hot Chemick.*—Hypochlorite sodium heated to 25° C. (77° F.).

Order of Chemick.	Strength in Chlorometric Degrees	Duration.
1st Chemick - -	0'35	5 hours
2nd Chemick - -	0'30	5 hours
3rd Chemick - -	0'20	4 hours

Cold Chemick.—Sodium hypochlorite at 12° to 15° C.

Order of Chemick.	Strength in Chlorometric Degrees.	Duration.
1st Chemick - -	0'65	3 hours
2nd Chemick - -	0'65	3 hours
3rd Chemick - -	0'50	3 hours

The same degree of whiteness is obtained with these chemicks provided the fabrics are lye-boiled in the same way.

It therefore devolves on the bleacher to see whether it will be more advantageous to be economical in coal or make a saving in hypochlorite of soda. If he cannot, for want of the necessary plant, preserve his chemicking liquors and is obliged to run them away after each operation, it is evident that it will be more profitable to employ weak, warm chemicks.

Preparation of the Fabrics to be Chemicked.—It is very important that the fabrics to be chemicked are not impregnated with water, because the water hinders the chemick from penetrating them, and retards its action much longer. The goods, therefore, should be allowed to drain well when they come in drenched from the bleaching green. It is a good plan to wring them, but that is not always possible. In such a case the chemick is made a little stronger. They should not be dry, as in that case the chemick may act on them too energetically. In such a case they should be moistened. When the fabrics come out of the lye-boiling keir it is not necessary to wash them in the machine. It is sufficient to run water on them in the keir to remove the lye, and let them drain. If a little lye remain, it will render the chemick a little alkaline and retard its bleaching power, but that does not injure the fabrics. The fabrics as they come from the keirs are still warm, their pores are open, and they are in very good condition for being acted on by the chemick. This observation is applicable—more especially so—to cotton goods, as linen fabrics are chemicked as they come back from the bleaching green.

Quantity of Chlorine Used on the Fabrics and Absorbed by them.—This quantity depends upon the manner in which the fabrics have been lye-boiled before the chemick. They will absorb so much the less the longer they have been lye-boiled, and the nearer they are to being bleached white.

First Example.—Eight hundred and fifty kilogrammes of cotton ribbons were lye-boiled in Mather's keir and first-chemicked in 5500 litres of liquor of 0.35° chlorometric

strength, and at the end of six hours this liquor titrated 0.28° chlorometric strength. The liquor thus lost strength to the extent of 0.7 chlorometric degrees. Therefore the quantity of chlorine absorbed by the fabrics was $5500 \times 0.7^\circ = 385$ litres of gaseous chlorine, according to the definition of the chlorometric degree or the equivalent of $\frac{3.85}{30} = 13$ kilogrammes of Brochoki's chlorozone (30° chlorometric to the kilogramme). As this liquid still titrated 0.28° chlorometric, it was advantageous not to run it away after use; it was preserved for a future operation. The total quantity of gaseous chlorine contained in the cistern was $5500 \text{ litres} \times 0.35^\circ = 1925$ litres, say 64 kilogrammes of chlorozone, and the quantity of gaseous chlorine per kilogramme of fabric was $\frac{1.925}{8.50} = 2.2$ litres. The quantity of gaseous chlorine absorbed by the kilogramme of fabric, $\frac{3.85}{8.50} = 0.45$ litre. The quantity of chlorinated liquid per kilogramme of fabric was $\frac{5.500}{8.50} = 6.5$ litres. The ribbons were piled in the cistern, curbed down, and a centrifugal pump circulated the chemick during the steep.

Second Example.—Three hundred and five pieces of cambric muslin weighing 1350 kilogrammes were chemicked for the first time in a liquor testing 0.24 chlorometric degrees. They were reeled twice in the chemick, and withdrawn after five hours' steep. At the end of this the chemick titrated 0.17° chlorometric strength. The quantity of liquid employed was $31,200$ litres, representing $31,200 \times 0.24^\circ = 7488$ litres of gaseous chlorine, or 250 kilogrammes of Brochoki's chlorozone. The cambrics were spread over four cisterns, each containing 7800 litres of liquid of 0.24° chlorometric strength. There were therefore 76 pieces in each cistern, but they generally contain 100 . Taking into account the quantity of liquid retained by the pieces, there were recovered per cistern 6000 litres of liquid of 0.17° chlorometric strength, say a total of $6000 \times 4 \times 0.17^\circ = 4080$ litres of gaseous chlorine, or the equivalent of $\frac{4.080}{30} = 136$ kilogrammes of Brochoki's chlorozone. The quantity of liquid employed per kilogramme of fabric was $\frac{31200}{1350} = 23$ litres, but generally it does not exceed 16 to

17 litres. The quantity of gaseous chlorine per kilogramme of fabric was $\frac{31200 \times 0.07}{1350} = 1.6$ litre.

Third Example.—Four hundred and eighty pieces of cambric muslin weighing 2000 kilogrammes were chemicked the second time in a liquor titrating 0.21° chlorometric strength. The pieces were reeled twice and steeped seven hours in the chemick. The titrations gave the following results :—

							Degrees Chlorometric Strength.
Original chemick	-	-	-	-	-	-	0.21
After 2 hours	-	-	-	-	-	-	0.20
After 4 hours	-	-	-	-	-	-	0.19
After 7 hours	-	-	-	-	-	-	0.19

It will be seen, therefore, that the chemick has no action after the first four hours. The fabrics should therefore be withdrawn at the end of that time. The quantity of liquid used was 39,000 litres, representing $39,000 \times 0.21^\circ = 8190$ litres of gaseous chlorine, or $\frac{8190}{30} = 273$ kilogrammes of chlorozone (30° to the kilogramme).

The chemick having fallen from 0.02° chlorometric strength, the total quantity of gaseous chlorine absorbed was $39,000 \times 0.02^\circ = 780$ litres, or $\frac{780}{30} = 26$ kilogrammes of Brochoki's chlorozone. Each kilogramme of fabric has absorbed $\frac{780}{2000} = 0.39$ litre of gaseous chlorine. The quantity of liquor recovered was $30,000 \times 0.19^\circ = 5700$ litres of gaseous chlorine, or $\frac{5700}{30} = 190$ kilogrammes of chlorozone. The remainder of the liquid was retained by the fabric.

Table of the Quantity of Chlorinated Liquid (Chemick) to be Used in Proportion to the Weight of Fabric.—This quantity depends upon the manner in which the fabrics are chemicked. The object of the table is to afford data for the construction of new cisterns, and a point of comparison with those already existing.

DIMENSIONS OF TANKS FOR PREPARING CHEMICKS. 225

Dimensions of the Cisterns.	Quantity of Liquid in litres.	Weight of the Fabrics.	Quantity of Liquid per kilogramme of Fabric.	Observations.
3 ^m x 2 x 1'80 Vol. 11,000 litres (2200 gals.)	7000 to 8000 (1540 to 1760 gals.)	1500 kilos to 2000 kilos (3300 to 4400 lb.)	4 to 4'6 litres (0'88 to 1'012 gals.)	The volume occupied by the fabrics is 6000 to 7000 litres. The fabrics are piled in the dry, curbed, and the liquid is run in below by a pump. This method of piling the goods is only suitable for spongy fabrics.
Round Cistern— Diam. 1'35 H. 1'10 Vol. 1560 litres	1100 (242 gals.)	150 kilos (330 lb.)	7'3 litres (1'606 gals.)	The chemick is prepared in the cistern and the fabrics are packed into it with the feet or by a stick.
3 ^m x 2 x 1'50 Vol. 9000 litres	7800 (1716 gals.)	450 kilos (990 lb.)	17 litres (3'74 gals.)	This tank is divided into two compartments for reeling the fabrics, which occupy in turn first one compartment and then the other.

Preparation of Chemicks.—Bleaching powders or hypochlorites sold in commerce or prepared in the works have a greater or less degree of strength, and must be diluted before use. To know the quantity of water which should be added to the liquid hypochlorite it is necessary to ascertain the chlorometric strength of the liquid; it is titrated by one of the known methods. If N be the chlorometric strength in degrees of the concentrated chloride, and N¹ that of the chemick which it is desired to make, it is required to determine the proportion of water and concentrated chloride to use to make L litres of chemick of N¹ degrees chlorometric strength. The number of litres of gaseous chlorine remaining constant, and calling the number of litres of concentrated chloride to be used X, we have—

$$L \times N^1 = X \times N, \text{ whence } X = \frac{L \times N^1}{N}.$$

Supposing that it be desired to make 3000 litres of chemick of 0.70° chlorometric strength, using Brochoki's chlorozone testing 35° , the number of litres to dilute with water to the volume of 3000 litres will be—

$$X = \frac{3000 \times 0.70}{35} = 60 \text{ litres.}$$

It is therefore necessary to take 60 litres of chlorozone and complete the volume of 3000 litres with 2940 litres of water; in actual practice and to simplify matters, 3000 litres of water and 60 litres of chlorozone. This will not make any sensible change in the strength, provided there be a considerable difference between the strength of the concentrated chloride and that of the chemick to be prepared. A similar calculation is made when it is desired to increase the strength of a chemick. Suppose that it be desired to raise 1000 litres of chemick of 0.5° chlorometric strength to 0.7° . The difference being 0.2° , the quantity X of chlorozone to employ would be—

$$X = \frac{1000 \times 0.2}{35} = 5.7 \text{ litres.}$$

So as not to be under the necessity of making these calculations each time, a table is prepared giving in one column the strength of the usual chemicks, and opposite, in the other column, the quantity of concentrated chloride of a certain strength to use in order to have 1000 litres of chemick. The liquid chloride of lime obtained by working up the solid chloride of lime with water is generally 8° in chlorometric strength. This strength of 8 chlorometric degrees supposes that 80 kilogrammes of chloride of lime of 100° strength have been worked up with 1000 litres of water (say 80 lb. per 100 gallons).

LIQUID CHLORIDE OF LIME OF 8° CHLOROMETRIC STRENGTH.

I.	II.	Remarks.
0°10'	12'5	The first column gives the chlorometric strength of the desired chemicks.
0°20'	25	
0°30'	37'5	
0°40'	50	
0°50'	62'5	
0°60'	75	The second column indicates the number of litres or gallons of chloride of 8° chlorometric strength which is required to be diluted with water to a volume of 1000 litres or gallons respectively so as to have a chemick of the strength indicated opposite.
0°70'	87'5	
0°80'	100	
0°90'	112'5	
1°00'	125	
1°25'	157'25	
1°50'	187'50	
1°75'	218'75	
2°00'	250	
2°25'	281'25	
2°50'	312'50	
2°75'	343'75	
3°00'	375	

CHLORIDE OF SODA OF 35° CHLOROMETRIC STRENGTH OR BROCHOKI'S CHLOROZONE.

I.	II.	Remarks.
0°05'	1'43	The first column gives the chlorometric degrees of the desired chemick.
0°10'	2'86	
0°15'	4'30	
0°20'	5'75	
0°25'	7'15	
0°30'	8'58	The second column indicates the number of litres or gallons of chlorozone of 35 chlorometric degrees which it is required to dilute with water to 1000 litres or gallons respectively in order to get a chemick of the chlorometric strength indicated opposite.
0°35'	10'00	
0°40'	11'43	
0°45'	12'85	
0°50'	14'30	
0°55'	15'75	
0°60'	17'15	
0°65'	18'58	
0°70'	20'00	
0°75'	21'43	
0°80'	22'85	
0°85'	24'30	
0°90'	25'75	
0°95'	27'15	
1°00'	28'60	

CHAPTER XVI.

BLEACHING ENERGY OF HYPOCHLORITES.—*Chlorine Water*
—*Alkaline Hypochlorites* — *Remark on the Method of*
Estimating Chlorine—*Rapidity of Action of the Bleaching*
Energy of Hypochlorites—*Hypothesis as to the Composition*
of Hypochlorites.

PRODUCTION OF CHLORINE AND HYPOCHLORITES BY
ELECTROLYSIS.—*Theoretical Data connected with the De-*
composition of Sodium Chloride by Electrolysis—*Causes of*
Loss in Yield—*Plant for Producing Hypochlorites by*
Electrolysis—*Hermite's Plant*—*Brochoki's Apparatus*—
Leclanche's Apparatus.

REDUCING AGENTS AND THEIR FUNCTION IN BLEACHING.

ENERGY OF DECOLORIZING CHLORIDES AND BLEACHING
BY ELECTRICITY.

THESE two questions require to be treated consecutively. In fact, speaking correctly, we do not bleach by electricity, because this process of bleaching would consist in causing an electric current to traverse the substances to be bleached, which would transform the colouring principles into colourless substances, or at any rate render these coloured bodies soluble in water, so that they might be easily expelled by washing. Now Tailfer does not believe that such a result has ever been obtained, or even that any attempts have been made to work

out this line of ideas. As a matter of fact, bleaching by electricity consists in producing hypochlorites by electrolysis, and this method of bleaching is distinguished from others by the special properties which the hypochlorites thus obtained possess. By first studying the force or energy of bleaching powder we shall see to what the rapidity of its action is due, and then in the sequel why the hypochlorites obtained by electrolysis are more energetic than those obtained by chemical means.

Production of Chlorine and Hypochlorites by Electrolysis.—When an electric current is made to traverse a solution of hypochlorite of sodium, this hypochlorite is decomposed. The chlorine goes to the positive pole, the sodium to the negative pole. The sodium in presence of water decomposes, forms sodium hydroxide with disengagement of hydrogen. Simultaneously with the decomposition of the hypochlorite of sodium there is decomposition of water, oxygen goes to the positive pole, hydrogen to the negative pole, and, finally, at the positive pole there is formation of chlorine and oxygen, and at the negative pole formation of caustic soda and hydrogen. As soon as these bodies are generated they react one upon another in the nascent state, and the chlorine unites with the soda to form hypochlorite of soda. The rôle which the oxygen plays is not well understood; it perhaps unites with the chlorine to form hypochlorous acid. The hydrogen is in most part disengaged as such; another portion acts upon the hypochlorous acid, reducing it to hydrochloric acid with the final formation of sodium chloride. It thus militates against the end in view, viz. the formation of hypochlorite of soda. Different schemes and plans have been proposed for producing by this means chlorine, soda, and their compound hypochlorite of soda. In the first place it will be better to give some idea of the phenomena which accompany the electrolysis of sodium chloride.

Theoretical Data connected with the Decomposition of Sodium Chloride by Electrolysis.—The electromotive force required to decompose chloride of sodium is 4.2 volts, and under this

tension an ampere disengages in one hour 1'331 gramme of chlorine or 0'420 litre of gaseous chlorine. On the other hand, a horse-power of 75 kilogrammetres = 736 watts. As the watts equal the product of the volts by the amperes, the number of amperes which gave 736 watts under a tension of 4'2 volts may be easily found. This number is equal to $\frac{736}{4.2} = 175$ amperes, which disengage in an hour $175 \times 1'331$ gramme = 232'92 grammes of chlorine or $175 \times 0'420$ litre = 73'5 litres of chlorine. Therefore, theoretically, in the decomposition of chloride of sodium it requires one horse-power to liberate in an hour 232'92 grammes of chlorine or 73'5 litres of gaseous chlorine.

Causes of Loss in Yield.—In practice this result cannot be attained, for the following reasons. (1) The mechanical power cannot be converted into electromotive force without a loss which varies from 5 to 20 per cent, according to the dynamo. A good dynamo generally furnishes in electrical work 0'83 of the mechanical force which it receives. Adopting this coefficient, a horse-power gives $736 \text{ watts} \times 0'83 = 610 \text{ watts}$. (2) The cable which transmits the electric current to the electrolyzer presents a certain resistance to the passage of the current and absorbs a certain amount of force. It is advisable therefore to use a massive cable so as to reduce this loss of force as far as possible. *Example.*—Supposing that one was working with a cable of 50 metres intended to transmit a current 100 volts, 100 amperes, and that it was desired to limit the loss of electromotive force to 3 volts. According to the formula $E = RI$, in which E represents the tension in volts, R the resistance in ohms, and I the intensity in amperes, we get

$$3 = R \times 100 \quad R = \frac{3}{100} = 0'03 \text{ ohm.}$$

Now, the resistance of a brass wire 1 metre in length of a section of 1 square millimetre is 0'016 ohm. The section S of a conductor of 50 metres in length and offering 0'03 ohm resistance will be in square millimetres—

$$S = \frac{50 \times 0'016}{0'03} = \frac{0'8}{0'03} = 27 \text{ square millimetres.}$$

About 3·5 amperes are passed per square millimetre of section. It is necessary to choose a cable massive enough for the loss of electromotive force due to the resistance not to exceed 5 per cent of the total voltage to be transmitted. (3) An electric current in traversing a saline solution to be electrolyzed suffers a resistance which heats the solution, and a portion of the work of the electric current is converted into heat. It is advantageous to diminish this resistance, and it is done by bringing the electrodes as near to each other as possible, and concentrating the salt liquor to the point which corresponds with its maximum degree of conductivity. A solution of sodium chloride attains this maximum point when it has a density of 24° B. The conductivity of copper being represented by 100,000,000, the conductivity of the salt solution is then about 40. Its conductivity compared with that of copper is therefore

$$\frac{40}{100,000,000} = \frac{1}{2,500,000}$$

Example.—Suppose that the electrodes are at a distance of $l = 0\cdot10$ metre, that the section of the salt liquor which separates the two is 2000 square centimetres, and that the current has a force of 100 amperes. It is required to find what is the theoretical loss of voltage due to the resistance of the salt solution. This loss of voltage is given by the formula $E = RI$. It is required to find what is the resistance in ohms of the salt solution. A copper wire 1 square centimetre in section, or 100 square millimetres, and 1 metre in length offers a resistance of $0\cdot00016$ ohm; therefore the resistance of the solution, the conductivity of which is $\frac{1}{2,500,000}$ compared with copper, the section $S = 2000$ square centimetres and the length $l = 0\cdot10$ metre, will be

$$R \frac{2,500,000 \times 0\cdot10 \times 0\cdot00016}{2000} = 0\cdot02 \text{ ohm.}$$

By bringing this value R into the formula $E = RI$ we get

$$E = 0\cdot02 \times 100 = 2 \text{ volts.}$$

The loss of voltage due to the resistance of the solution is in this case 2 volts.

To find what will be the heat of the salt solution we have

$$C = \frac{RI^2}{g \times 424};$$

C being the number of calories, 424 kilogrammetres the mechanical equivalent of 1 calorie, and $g = 9.81$ the acceleration of gravity.

*Therefore, in the present instance,

$$C = \frac{0.02 \times 100^2}{9.81 \times 424} = 0.05$$

or 0.05 calorie per second, and per hour $3600 \times 0.05 = 180$ calories. If there be 30 litres of liquid in the vessel, the elevation of temperature will be 6° C. per hour. (4) The electric current, at the same time that it decomposes the sodium chloride, also decomposes the water, which only requires 1.5 volts of electromotive force for its decomposition. The law according to which the relative proportions of water and sodium chloride are determined is not known; it depends on the surface of the electrodes, their distance apart, and perhaps also on the total voltage, and the degree of concentration of the salt solution. (5) The chlorine, which is disengaged at the positive pole, cannot entirely be collected in the form of hypochlorite of soda. Caustic soda, oxygen, and hydrogen are also produced. The hydrogen has a tendency to unite with the chlorine to form hydrochloric acid, and this hydrochloric acid in the presence of soda yields sodium chloride and water. If the temperature of the liquid exceeds 32° to 35° C., the hypochlorite of soda partially decomposes, yielding chlorate.

Plant for Producing Hypochlorites by Electrolysis.—There are two kinds. In the first, the hypochlorite is produced in contact with the electrodes; in the second, the chlorine and the soda are prevented from combining in the electrolyzer, and are combined afterwards in another apparatus to form hypochlorite. *Hermite's Plant.*—See illustration, Fig. 35. It

consists of a galvanized iron tank, in the bottom of which is a pipe pierced with small holes, through which the solution arrives. This solution, partly converted into hypochlorite, runs out by the rimmed edges of the tank, which serve as exit channels. The cathodes are formed of zinc discs mounted on an axis which revolves slowly. The anodes of platinum foil are intercalated between each cathode. The platinum foils are kept rigid by ebonite frames and are soldered in their upper part to sheets of lead. The sheets of lead bind them to a bar of copper, through which the current comes. In

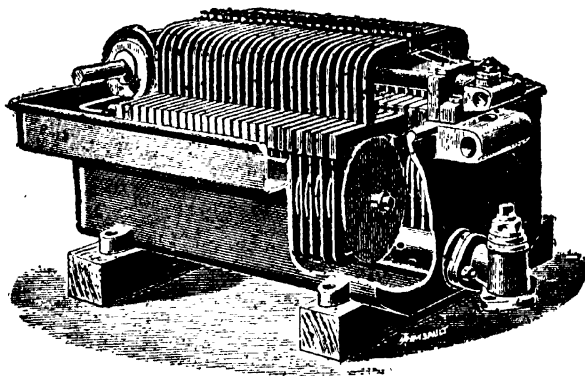


FIG. 35.—Hermite's electrolyzer.

this way all the sheets of platinum are connected on the surface, and the same is the case with the zinc discs, which are connected together by their axes. The sheets of zinc as they turn rub against a flexible sheet of ebonite and are thus kept constantly clean. Hermite gives the following particulars regarding his apparatus. He uses magnesium chloride in preference to sodium chloride because it requires less electromotive force to decompose it, and because hypochlorite of magnesia of equal chlorometric strength has a more rapid and superior bleaching power than chloride of lime. Owing to the high price of magnesium chloride he uses a solution of a mixture of magnesium and sodium chlorides. Magnesium

chloride is transformed into hypochlorite, and the sodium chloride serves to render the solution more conductible. The following are the proportions:—

	Parts. 1000
Water - - - - -	1000
Sodium chloride - - - - -	50
Magnesium chloride - - - - -	5

The flow is so regulated that the solution attains a suitable degree of strength, and it is propelled into the chemicking cistern, where the bleaching is effected. The operation finished, the liquid is propelled by a pump into an upper tank, whence it returns to the apparatus to be again electrolyzed. According to Hermite the following reactions occur in the process of bleaching. The oxygen acts on the colouring principles, which it oxidizes with formation of carbonic acid; the chlorine produces hydrochloric acid, which, in presence of magnesia, combines with it to re-form the original magnesium chloride. The same chloride of magnesia can thus serve indefinitely. The only loss is in the quantity of saline solution retained by the fabrics being bleached. Hermite states that with his apparatus a motive force of 10 horse-power can produce in twenty-four hours the equivalent of 100 kilogrammes, say 2 cwt. of chloride of lime at the following cost:—

1.—Works with Hydraulic Power.

	Francs.
(1) 10 hydraulic horse-power, nominal.	
(2) 30 kilos common salt at 0·05 franc per kilo - - -	1·50
(3) 6 kilos magnesium chloride at 0·12 franc per kilo - - -	0·72
(4) Depreciation of electrical plant - - - - -	3·00
	<u>5·22</u>

2.—Works with Steam Power.

	Francs.
(1) 10 horse-power for 24 hours, 240 kilos of coal at 20 francs the ton - - - - -	4·80
(2) Common salt, 30 kilos at 0·05 franc the kilo - - -	1·50
(3) Magnesium chloride, 6 kilos at 0·12 franc the kilo - - -	0·72
(4) Depreciation of electrical plant - - - - -	3·00
	<u>10·02</u>

(Say 48. a cwt.) per kilo.

To this must be added the cost of superintending the working of the apparatus. If the apparatus be small the workman can attend to something else at the same time. It is well to observe that it is not the 6 kilogrammes of magnesium chloride which produce the equivalent of 100 kilogrammes of chloride of lime. These 6 kilogrammes of magnesium chloride as well as the 30 kilogrammes of chloride of sodium are intended to replace the salts which have been retained by the fabrics to be bleached, but it is the magnesium chloride produced by the decomposition of the magnesium hypochlorite during the bleaching which is electrolyzed afresh, and that indefinitely.

Yield of Hermite's Apparatus.—On the supposition that the dynamo gives a return of 90 per cent, 10 horse-power will give

$$10 \times 0.90 \times 736 \text{ watts} = 6624 \text{ watts.}$$

The electromotive force absorbed by a cistern being 5 volts, the number of amperes will be $\frac{6624}{5} = 1325$ amperes, and as an ampere liberates during one hour 0.420 litre of chlorine, in twenty-four hours there would be produced

$$24 \times 1325 \times 0.420 \text{ litre} = 13,356 \text{ litres of chlorine.}$$

100 kilogrammes of chloride of lime containing the equivalent of 10,000 litres of chlorine, the yield of Hermite's apparatus would be in this case

$$\frac{10,000}{13,356} = 0.72 \text{ or } 72 \text{ per cent.}$$

Brochoki's Apparatus.—The general plan of this apparatus is illustrated in Fig. 36. It consists of an ebonite case divided into five compartments. In each compartment there are three sheets of lead, and two sheets of platinum are intercalated between the sheets of lead. The platinum foil is kept rigid by an ebonite frame, and is soldered in its upper part to a copper rod. The sheet of lead in the middle connects with a gutter, and leaves an empty space between its lower edge and the bottom of the case. *Direction of the Current.*—The illustration shows how the leads and the platinum are joined. In each compartment the two sheets of platinum are joined

together on the surface as well as the three sheets of lead, and from one compartment to another the connection is made in tension. The current arrives at the platinum of the first compartment, traverses the salt solution, electrolyzes it, and goes

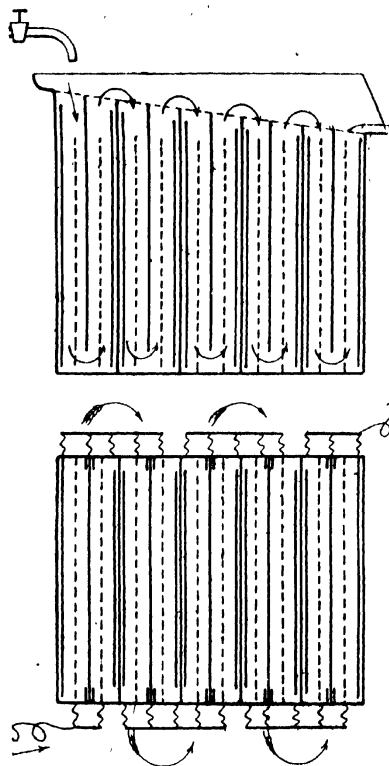


FIG. 36.—Brochoki's electrolyzer.

on to the leads. These leads are connected with the two platitudes of the next compartment. This compartment acts like the first, and so on. The difference of potential for each compartment is 5 volts; it requires, therefore, for a vat of five compartments an electromotive force of 25 volts. The

surface of the electrodes has been calculated to allow the passage of a current of 100 amperes, using a salt solution of 6° Baumé. The sheets of lead have a useful surface of $4 \times 0.30 \text{ metre} \times 0.30 \text{ metre} = 0.36 \text{ square metre}$. The platinum sheet has a surface of $0.36 \text{ metre} \times 0.28 \text{ metre} = 0.10 \text{ square metre}$, and as the two surfaces act in each sheet, and as there are two sheets in each compartment, the total surface is $4 \times 0.10 \text{ square metre} = 0.40 \text{ square metre}$. It will be seen, according to this, that a current of $\frac{100}{36} = 3$ amperes is passed per square decimetre. The distance between the sheets of lead and the platinum ones is 2 centimetres.

Course of the Salt Solution.—The salt solution is poured into the first part of the first compartment; it descends, passes under the sheet of lead, re-ascends into the second part of the first compartment; it diverts into the second compartment, where it circulates in the same way as in the first, and so on. The tops of the ebonite compartments of the vat, all sloping downwards, or diminishing in height towards the exit, the saline solution runs out at the lower extremity of the vessel, after having been gradually enriched in hypochlorite of soda in contact with the electrodes. Tailfer made numerous experiments with Brochoki's apparatus, which yielded to him the following results:—

(1) The sodium hypochlorite obtained is a neutral liquid, which is a very energetic bleaching agent. This liquid, of 1.25 chlorometric degree, can cream yarn in forty minutes, which takes sixty to eighty minutes to cream with chloride of lime of 2 chlorometric degrees. (2) The chlorometric strength obtained is always low; 1.5 to 2 chlorometric degrees would appear to be the maximum, and in the course of working it rarely exceeds 1 chlorometric degree. It is necessary that the outflow be rapid enough to prevent elevation of temperature. If the temperature exceeds 32° to 35° C., a portion of the hypochlorite is converted into chlorate. (3) This liquid, by the very fact that it is an energetic bleaching agent, is very unstable. From night till morning its strength lowers

from 1.5° to 0.75° chlorometric strength; it then continues to decompose more slowly. It is rendered more stable by the addition of a little soda. (4) It follows, from the feeble strength of the hypochlorite, that it entails reservoirs of considerable dimensions for storing it. (5) When the surface of the leads is clean a solution of 6° Baumé is of sufficient conductivity, but this surface oxidizes and resists the passage of the current. So as not to be under the necessity of increasing the voltage, the solution must be rendered a better conductor by concentrating it to 20° to 24° Baumé. (6) In the experiments undertaken by Tailfer, he endeavoured to re-electrolyze the salt solution after having used it for bleaching purposes, but he found that the yield by the second re-electrolyzation was very 'bad'; it did not exceed 10 to 15 per cent of the theoretical yield. (7) Under these circumstances, the expense in common salt becomes very considerable, because if hypochlorite of 1° chlorometric strength be produced, and if there be employed for the purpose a solution of 20° Baumé, say containing 200 grammes per litre, there will be 10 grammes of salt transformed into hypochlorite and 190 grammes lost, say 5 per cent of salt utilized and 95 per cent lost. The use of platinum electrodes renders the initial cost of the plant very high. Platinum always preserves its value, and, as far as it is concerned, there is nothing to be considered but the interest of the invested capital.

Leclanché's Apparatus.—In the two examples of apparatus which have been described the formation of sodium hypochlorite is effected in presence of electrodes; it is not possible, therefore, to obtain great chlorometric strength. By Leclanché's apparatus the same chlorometric strength may be obtained as by chemical methods. The construction of this apparatus is illustrated in Fig. 37. The chlorine and soda are prevented from combining in presence of the electrodes; they are collected separately and conveyed into another apparatus called an absorber, where they combine to form sodium hypochlorite. The anodes are made of special carbon and the cathodes of iron. A porous asbestos partition separates the

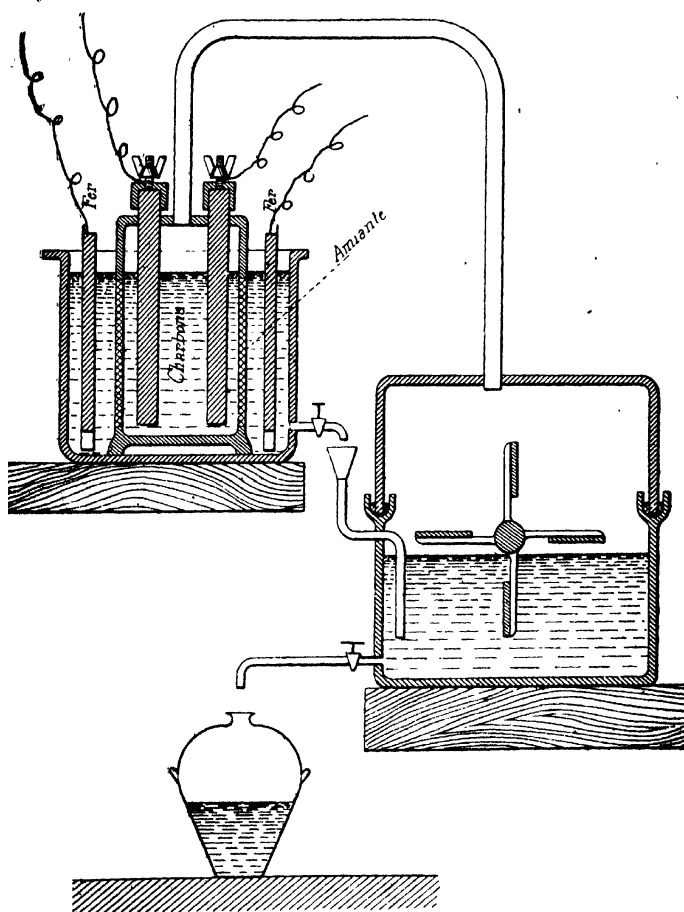


FIG. 37.—Leclanché's electrolyzer.

Fer = iron; Amiante = asbestos.

carbon electrodes from the iron electrodes. The carbon electrodes are placed inside a case closed on the top and the sides of which are constituted by the asbestos partition. This partition separates the chlorine from the soda. The soda, when it is concentrated to the desired strength, is collected in a reservoir, from which it is led into the absorber. The chlorine is disengaged along the length of the carbons, and fills the upper part of the case, from which it is led by earthenware pipes into the absorber previously charged with soda. A mixer fitted with arms puts the soda in motion so that it may absorb the chlorine. A liquid may thus be obtained titrating 15, 20, 25, 30, and 35 chlorometric degrees, depending on the strength of the soda which is in the absorber. The salt solution is concentrated to 22° to 24° Baumé. It contains about 250 grammes of salt per litre. The quantity of salt utilized varies between 50 and 95 per cent, but it is not advisable to endeavour to exceed this limit, as the electric yield is much diminished. In each particular case a decision has to be come to as to whether it is more advisable to economize salt or motive power, and consequently what is the most advantageous chlorometric strength to produce.

Cost of Production.—The cost depends on the plant already in existence in the works, and the extent of the new plant which it is desired to instal. The following example is given to show the economy of the process.

Suppose a hydraulic force of 20 horse-power is at disposal, 40 litres of sodium hypochlorite of 15° chlorometric strength can be produced hourly with a dynamo of 100 volts, 100 amperes, or 10,000 watts; there is every interest therefore to work twenty out of the twenty-four hours. There will thus be produced 800 litres of this liquid daily equal to 400 kilogrammes of hypochlorite of soda of 30° chlorometric strength, the price of which varies in different countries from 15 to 18 francs the 100 kilogrammes—say a quantity of hypochlorite which costs 60 to 72 francs on the market. The expense using Leclanché's apparatus would be :—

	Francia.
(1) 800 litres of salt solution, 250 grammes per litre, the salt costing 5 francs the 100 kilos, 800×0.250 kilo \times 0.05 franc	10
(2) Labour, attendance day and night	8
(3) Sundry expenses, lubrication, maintenance, wear and tear of carbons	4
	<u>22</u>

This leaves 40 to 50 francs per day as profit and as a sinking fund to pay the cost of the plant.

Now an installation of this capacity costs :—

	Francia.
Cost of a dynamo	2500
Cost of erection, foundations, shafting, pulleys, belts	2500
Electrolyzer and absorber	10,000
Cost of erection, conducting cable, pump, reservoir, piping	3000
	<u>18,000</u>

The plant pays for itself in a year and a half and afterwards an economy of 40 to 50 francs per day is effected. When the motive power is produced by a steam engine it is necessary to add 1.2 kilogramme of coal per horse-power per hour (a good Corliss engine hardly consumes 0.8 kilogramme), say an extra expense, reckoning coal at 20 francs the ton, of

$$20 \text{ hours} \times 20 \text{ H.P.} \times 1.200 \text{ kilo} \times 0.02 \text{ fr.} = 9.60 \text{ fr.}$$

With supplementary expenses the daily gain is reduced to 25 francs. In this latter case, if the bleacher does not take into account the advantages of greater security and the greater durability of the fabrics, there is no advantage in erecting a special engine for this purpose, but if the existing engine has 20 disposable horse-power there will still be a profit of 7500 francs annually after a two years' sinking fund. If a hydraulic force of 40 horse-power be at disposal, the economy realized will be much more considerable, because the working expenses remain practically the same and the cost of the first installation does not amount to much more. The above examples of the production of electrolytic hypochlorites have been given by the author because he took part in the experiments the

results of which are given above. But there are many other processes of producing hypochlorites by electrolysis. The above examples have been cited with the object of showing what may be expected from these processes and of enabling the reader to appreciate beforehand whether the particular circumstances under which he may be placed are such as to warrant him in hoping to be able to produce electrolytic hypochlorites advantageously.

REDUCING AGENTS AND THEIR FUNCTION IN BLEACHING.

Sodium Bisulphite.—Sodium bisulphite is generally met with in the liquid form as a pale yellow or colourless solution. Its formula is NaHSO_3 , and it smells of sulphur dioxide. It is prepared by saturating carbonate of soda by sulphurous acid and keeps well if stored in closed vessels. The density of solutions saturated at about 15°C . (59°F .) is about 1.35, at a lower temperature crystals are precipitated which decompose when heated in the air. Sodium bisulphite is an important bleaching agent. It may contain, besides the bisulphite, neutral sulphite or sulphurous acid in excess. A solution of about 35°B . contains 22 to 23 per cent of sulphur dioxide.

Estimation of Free Sulphurous Acid.—Dissolve 10 grammes of the sample in distilled water in a graduated 200 cubic centimetre flask; draw off 20 cubic centimetres by means of a pipette and titrate the acidity by decinormal soda, using methyl orange as indicator.

$$1 \text{ cubic centimetre} = \frac{N}{10} \text{ soda} = 0.0032 \text{ SO}_2.$$

Estimation of Total Sulphurous Acid.—Draw off 20 cubic centimetres of the above solution, add a few drops of starch paste and run in $\frac{N}{5}$ to a blue colour.

$$1 \text{ cubic centimetre} = \frac{N}{5} \text{ iodine} = 0.0064 \text{ of SO}_2.$$

Estimation of Neutral Sulphite.—If there be no free sul-

phurous acid draw off 20 cubic centimetres of the initial liquor and titrate by $\frac{N}{10}$ sulphuric acid and calculate to SO_2 combined as sulphite.

$$1 \text{ cubic centimetre } \frac{N}{10} \text{ acid} = 0.063 \text{ neutral sulphite.}$$

Bisulphite of soda in solution should respond to the following tests. Treated by an acid it should disengage sulphurous acid without generating any turbidity nor precipitating hyposulphite. Nitrate of silver should give no cloudiness. Barium chloride should not give an appreciable precipitate.

DENSITY OF SOLUTIONS OF SODIUM BISULPHITE AT 15° C.

Degrees Density.	Degrees Baumé.	NaHSO ₃ per Cent.	SO ₂ per Cent.	Degrees Density.	Degrees Baumé.	NaHSO ₃ per Cent.	SO ₂ per Cent.
1.008	1	1.6	0.4	1.171	21	16.5	10.2
1.022	3	2.1	1.3	1.190	23	18.5	11.5
1.038	5	3.6	2.2	1.210	25	20.9	12.9
1.052	7	5.1	3.1	1.240	27	23.5	14.5
1.068	9	6.5	3.9	1.252	29	25.9	15.9
1.084	11	8.0	4.8	1.275	31	28.9	17.8
1.100	13	9.5	5.7	1.298	33	31.7	19.6
1.116	15	11.2	6.8	1.321	35	34.7	22.5
1.134	17	12.8	7.8	1.345	37	38	23.6
1.152	19	14.6	9.0				

Free sulphurous acid and bisulphites are titrated with normal caustic soda and phenolphthalein, the normal sulphites with normal acid and methyl orange. If methyl orange be added to a bisulphite solution a red coloration indicates an excess of acid over the amount required to form NaHSO_3 , which excess is estimated by titration with normal soda to the point of neutrality. If, however, the solution is coloured yellow by methyl orange normal sulphite is present which may be estimated by titration with normal acid.

N.B.—Reducing agents act in a diametrically opposite manner to oxidizing agents like chlorine and bleaching powder, so much so that sodium hyposulphite is known as anti-chlor from its use in removing the last trace of chlorine from fabrics.

CHAPTER XVII.

SOURS.

PROPERTIES OF THE ACIDS.—*Hydrochloric Acid—Sulphuric Acid—Acetic Acid—Oxalic Acid.*

EFFECTS PRODUCED BY ACIDS.—*Lime Sour or Grey Sour—Duration of Steep—Temperature of the Sour—Strength of Sour—Method for Strengthening previously used Acid.*

SOURING CISTERNS.

PROPERTIES OF THE ACIDS.

THE acids generally used in bleaching are hydrochloric and sulphuric acid, more rarely, oxalic and acetic acids.

Hydrochloric Acid.—Hydrochloric acid, or muriatic acid, is a gas, generated by the action of sulphuric acid on common salt, the reaction forming the first stage in the Leblanc process of alkali manufacture, and liquid hydrochloric acid is a solution of this gas in water. The density of the hydrochloric acid of commerce is 1.13°, and it registers 22° with Baumé's hydrometer. When pure it is colourless, but the commercial acid is coloured yellow by a trace of iron. Its price varies between say 2s. to 2s. 6d. per cwt.

Sulphuric Acid.—For the manufacture of this acid the reader is referred to a textbook of chemistry. Sulphuric acid is an oily liquid, colourless if pure, blackish-yellow if it has been in contact with organic matter, which it burns. It has, when concentrated, a density of 1.84, and registers 66° Baumé or 168° Tw. The temperature of the liquid should be 15° C. When taking the density never add strong acid to hot water or vice versa. In diluting the acid run the acid into the water and not the water into the acid.

Hydrochloric Acid 22° B.		Sulphuric Acid 66° B., 168° Tw. Sp. Gr. 1·840.	
Degrees Baumé.	Number of litres per cubic metre, or gallons per 100 gallons.	Degrees Baumé.	Number of litres per cubic metre, or gallons per 100 gallons.
0·1	4·5	0·1	1
0·2	9	0·2	2
0·25	11	0·25	2·1
0·5	22·5	0·5	4
0·75	34	0·75	7
1	45	1	8
1·5	70	1·5	12
2	90	2	17

Baumé's hydrometer is used to test the strength of the sours, but care must be taken to work at 15° C.

Acetic Acid.—Acetic acid is one of the products of the destructive distillation of wood. It may contain tar, sulphurous acid, and sulphuric acid, originating in the decomposition of the acetate of lime by sulphuric acid. Acetic acid, if not too strong, does not attack vegetable fibres, and the salts which it forms with carbonates and hydrated oxides are very soluble. These two properties adapt it well for use in bleaching, and it is to be regretted that its high price forms an obstacle to its use.

Oxalic Acid.—This is used in the form of oxalic acid, oxalate of potash, acid oxalate of potash. Oxalic acid dissolves salts of iron; it is used to remove rust stains and the yellow tint which ferruginous water imparts to the fabrics. Highly poisonous. Antidote: washing soda, magnesia, or chalk.

Effects Produced by Acids.—Acids diluted with water to a suitable strength do not exert an injurious action on vegetable fibres; they slightly attack the colouring matter of linen and cotton, rendering it brighter, but their rôle in bleaching is to free the fabrics from deposits and dirt, as well as from the salts which they retain after the lye-boils and the chemicks.

The alkaline lyes dissolve resinous principles, forming more or less soluble soaps. The washings which follow the lye-boils remove these substances, but not always completely.

For example, after the washing following the lime-boil the fabrics must be soured with hydrochloric acid to remove all trace of lime. A sour following a first lye-boil with soda produces very good results and prepares the fabrics well for the next boil. The fabrics as they come from the chemick retain a yellow tint even after washing. A sour removes this tint and drives off all trace of chlorine. Hydrochloric acid makes a suitable sour after lime (*Grey sour*) or soda, especially after lime, as sulphuric acid would form, with lime, sulphate of lime, an almost insoluble salt. After the chemick, sulphuric acid is used in the *White sour*, because its action on the fabric is preferable. The last bleaching operation should be a sour, because it leaves the fabric with the brightest colour and the one most pleasant to the eye. But this sour must be followed by especially good washing. Otherwise, when the fabrics are blued, the blue, especially ultramarine blue, is quickly destroyed by the traces of acid remaining. When any acid remains in the fabrics, it is very injurious to them, especially when they are dried in that condition; if they are then ironed with a hot iron, they lose their soundness and are more or less burnt. This is the reason why bleachers who do not possess washing machines perfect enough for this purpose only give a wash after the first chemick. Others prefer for a final operation a weak boiling with carbonate of soda lye slightly tinted with blue, or a soaping, the whole followed by a wash. If the whole of the soap be not well removed the fabrics will have a great tendency to turn yellow in the warehouse. Some bleachers steep the fabrics from twenty to thirty minutes in a weak hydrochloric acid sour, heated to about 90° C. (194° F.). This operation brightens up the heart of the fabrics and removes grease, but it is especially useful in removing the yellow tint due to ferruginous waters. If the waters be not ferruginous, a sulphuric acid sour, well given as a finish, will produce the same effect and cost much less. When parts of the fabrics are of different colours it is not prudent to sour them, as some colours would not resist dilute acid and would be more or less attacked. In such a case they are not soured, or, if so, the

pieces are run rapidly through a souring cistern containing very dilute sulphuric acid (1 litre per cubic metre, or 1 gallon per 1000 gallons), and then washed immediately. If the sulphuric acid be still too energetic, oxalic acid is used, the action of which is not so rapid. Oxalic acid may be replaced by acetic acid. Oxalic acid brightens blue colours, and acetic acid brightens black colours. In order to ascertain the strength of the sours made with these two acids, the workmen dip their finger in the acid and put it in their mouth. The acid should slightly "bite" the tongue. A double roller washing machine answers very well for souring; the acid is in the first cistern, and water constantly being renewed for washing in the second.

Rough Sour.—"This sour is given to fabrics as they come from the bleaching green before they have been in any way chemicked. It is thought that it opens the fibres of the yarn and enables the chemick to act more effectually in the subsequent operation. It is also thought to cause the greenish tint which begins to show itself at this stage to disappear. Some old bleachers do not give a 'rough sour'. They say that it hardens the yarn, and that the chemick cannot, therefore, penetrate into the heart of the fabrics. But that is no explanation, since the sour brightens the fabrics and removes the deposits which remain therein after boiling. When the fabrics come out of this sour they are more supple to the touch than when they come out after being boiled, and the heart is brighter. Sometimes it economizes one of the bleaching operations, because, when the fabrics are taken at the right time, and soured in this way, the resultant effect contributes greatly in quickly producing a perfect white" (*Hints to Bleachers*). Tailfer has not used this sour immediately before the first chemick, but he has given, with much success, a hydrochloric acid sour between the first and the second boiling.

General Recommendation.—Whatever may be the arrangements made for souring, they ought to be such that the fabrics are well impregnated all throughout their parts. None of them should be exposed to the air and dry there, either by swimming

above the cistern or in the interval between the sour and the washing. That is why the fabrics are washed as soon as they come from the sour.

Duration of Steeps.—When strong sours are used, i.e. when the gravity varies between 1° and 2° Baumé, a three hours' steep is sufficient. When weak, i.e. when their gravity is less than 0.25° Baumé, a ten to twelve hours' steep is necessary. If the fabrics be not steeped long enough, there will not be time for the effect to be produced; but there is no disadvantage in leaving them longer in the sour; they may remain a day or two without being damaged. If it be not desired that the fabrics be steeped for such a long time, and it be not possible to wash them forthwith, the acid is run off, or run into another cistern, and replaced by water. By renewing the water every twenty-four hours the fabrics may be left for three or four days in the souring cisterns without risk.

Temperature of the Sour.—Sours heated to 25° to 30° C. (77° to 86° F.) have much greater action than cold sours. Weak hot sours may, therefore, replace cold strong sours, and the same result be obtained.

ACIDITY OF THE SOURS.

First Method.—Mix the acid in the cistern, and heat to 27° C. (81° F.). Throw in the untied bundles, and immerse them with a stick; or, better still, a man packs them with his feet by tramping upon them. Sours are made in the following proportions:—

Hydrochloric acid sour after lime: 5 litres of acid per cubic metre of water (or 5 gallons per 1000 gallons). Sulphuric acid sour after chemick: 2 to 3 litres of acid per cubic metre of water (2 to 3 gallons per 1000 gallons). These sours are suitable for squeezed fabrics, because, if impregnated with water, acid would not penetrate them, and its action would be insufficient. After ten hours these acids are exhausted, and are not worth recuperating.

Second Method.—If the fabrics be not squeezed, the follow-

ing sours are used, after heating to 27° C. (81° F.). The steep lasts six to twelve hours. Hydrochloric acid sour after lime: 0.5° to 0.75° Baumé, or 22 to 34 litres per cubic metre of water (22 to 34 gallons per 1000 gallons). Sulphuric acid sour after chemick: 0.5° Baumé, or 4 litres per cubic metre of water (4 gallons per 1000 gallons). In regard to calicoes, a mixture of hydrochloric and sulphuric is used after the chemick in the ratio of 4 litres of sulphuric acid and 4 litres of hydrochloric acid per cubic metre of water (4 gallons of each per 1000 gallons of water).

Third Method.—If the sours be not heated, and if the fabrics be not squeezed, the following strengths are used with a three hours' steep. Hydrochloric acid sour after lime: 2° Baumé, or 90 litres of hydrochloric acid per cubic metre of water (90 gallons per 1000 gallons). Sulphuric acid sour after chemick: 1° Baumé, or 8 litres of sulphuric acid per cubic metre of water (8 gallons per 1000 gallons). If a mixture of sulphuric and hydrochloric acid be used for souring calicoes, 8 litres of sulphuric and 4 litres of hydrochloric acid are used per cubic metre of water (or 8 gallons and 4 gallons per 1000 gallons). *Remark.*—The sours of these two last categories should not be run away; they should be preserved for another operation, after having added the acid which has been absorbed by the fabrics. They are only thrown away when too dirty. Whatever strength of sour be used, the bleacher ought to satisfy himself that the acid has penetrated well into all the parts of the fabrics. As they come out of the sour they should all present a uniform tint; there should be no yellow or grey portions alongside bright parts. If the fabrics be bulky and compact, it is well to pass them through a saturating beck filled with sour.

Method of Reinforcing the Strength of previously used Sour.—The strength of fresh acids is tested by Baumé's hydrometer, taking care to cool the acid to about 15° C. (say 60° F.). If the acid which has been used be tested, it will be seen that its gravity has not changed appreciably, because the substances dissolved preserve its original density. To ascertain the

quantity of acid absorbed, it is tested to see how much soda is required to saturate 10 cubic centimetres of the original sour, and how much to saturate 10 cubic centimetres of the same sour after use. The difference between these two quantities gives the proportion of acid absorbed. For weak sours 10 grammes of caustic soda are dissolved in a litre of water. Take 10 cubic centimetres of the fresh sour and colour it red with litmus. Fill a graduated burette with the soda solution, and run it in, drop by drop, until the red turns blue, and note how many divisions you have run in. Recommence the same operations with 10 cubic centimetres of the sour which has been used, and note the number of divisions used. Suppose that in the case of the original sour you have run in 30 divisions, and 20 in the case of the sour that has been used, these figures would indicate that one-third of the acid had been absorbed. To bring the sour to the strength necessary for a further operation, it will be necessary to add one-third of the acid used for the original sour. This test is not made for each sour; it is verified two or three times, and the same quantity always added to revivify the sour. The bleacher confirms, by Baumé's hydrometer, if the gravity is about what is wanted. The sours for fabrics coming from the chemick may last several months; they are run off when too dirty. The sours for fabrics coming from lime bucking become dirty much sooner.

Souring Cisterns.—In the construction of these cisterns, materials are used which are not attacked by acids. Cisterns of granite, with cement joints, resist weak acids very well. Generally lead-lined pine-wood becks are used. Lead costs dear, and, besides, has the inconvenience, if thin sheets are used, of tearing very readily. The best thing is to use well-jointed wooden becks without any inside lining whatever. The sides of the beck should not be crossed by iron rods, for in a very short time the wood is impregnated with acid, which rusts the iron. The boards must be well joined match-board-wise or otherwise outside; wooden cross pieces joined together by bolts will keep the boards pressed one against the

other. Wooden becks ought to be placed so that they can be easily got at for repair and inspection. When several cisterns are laid down, one after another, they communicate together by lead pipes. Cast-iron or bronze taps are quickly attacked by acids; it is preferable to use ebonite or stoneware taps, in spite of their fragile nature. The author has also used wooden taps, which resist feeble acids very well, and have, moreover, the advantage of not costing much. The sours are transferred from one cistern to another by a pump or injector. The centrifugal pumps should be of bronze, and not of cast iron, and in spite of that they wear very rapidly. If the sours be strong, ebonite or earthenware pumps should be used. Injectors are very convenient for transferring the weak acids used as sours; the steam dilutes them a little, and raises their temperature, which is no very serious inconvenience, since these sours are used at a temperature of 25° C. (77° F.). Tailfer successfully used Koerting's injectors, made of special metal, which acids attack but little. This firm also makes them in porcelain. These appliances, to work well, must be placed opposite the bottom of the cisterns. They should only work by pressure. It is very advantageous as in chemicking to saturate the fabrics with acid before piling them in the cistern. This saturation may be done in a roller washing machine or by simply running them through a small cistern.

CHAPTER XVIII.

LINEN BLEACHING: EXAMPLES OF METHODS.

LINENS.—*Light hand-spun Cambrics, etc.*—*Light Cambrics (machine-spun)*—*Cambrics, Cambric handkerchiefs (boiled yarn), Household linen*—*Cholet Cambrics and Cholet handkerchiefs in Cholet white*—*Fine linens and sheetings, full white*—*Coarse North of France or Normandy sheeting (cream yarn)*—*Ordinary white*—*Fine white*—*Three-quarters white*—*Half White*—*Sponging*—*Fine Cambric or Cholet handkerchiefs with coloured border, spun from half white yarn.*

Light Hand-spun Cambrics, etc.

(1) Steep in hot water, twelve to twenty-four hours; hand-wash; squeeze. (2) First lye-boil, eight to ten hours, with a lye of 1.4° to 1.6° B., made from a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent, with rosin soap; atmospheric pressure; wash in keir; squeeze. (3) Sour, hydrochloric acid in proportion of 5 litres to cubic metre; temperature, 27° C.; hand-wash; squeeze. (4) Second lye-boil, same as first; wash in keir; squeeze. (5) Expose on bleaching green for twenty-four hours. (6) Wash in the stocks with olein soap and third lye-boil, same as second; wash in keir; squeeze. (7) Expose on the green twenty-four hours. (8) Wash with soap in stocks and fourth lye-boil, same as third. (9) Expose on bleaching green twenty-four hours. (10) Sorting out: first category—to be chemicked; second category—wash with soap in stocks, fifth lye-boil with sal soda, and exposure on green. (11) First chemick, of 0.15 chlorometric degree;

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temperature, 25° C. (77° F.); steep five hours; hand-wash; squeeze. (12) Sour, sulphuric acid; 3 litres of acid per cubic metre (say 3 gallons acid per 100 gallons water); temperature, 27° C. (80·6° F.); hand-wash; squeeze. (13) Boil with olein soap, followed with lye-boil (salt of soda, 1·3° Baumé); wash in keir; squeeze. (14) Expose on green for twenty-four hours. (15) Second chemick, of 0·1° to 0·12° chlorometric degree; temperature, 25° C. (77° F.); steep five hours; hand-wash; squeeze. (16) Sour, sulphuric acid, same as after first chemick. NOTE.—In summer the fabrics are very white. The second chemick is suppressed, and the fabrics are simply soured. (17) Lye-boil with a lye of 1·3° Baumé, made from a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent, with olein soap. (18) Hand scouring in a bath of white soap or olein soap. (19) Sorting out: first category—wash by running on hot water from above; expose on green. Second category—lye-boil with a lye made from a mixture of caustic soda 20 per cent, carbonate of soda, 80 per cent, 1° Baumé; wash in keir and expose on green. (20) Sour, hydrochloric acid, in proportion of 4 litres per cubic metre (4 gallons per 1000 gallons); temperature, 27° C. (80·6° F.); hand-wash; squeeze. (21) Boil with olein soap, hand-rub. (22) Sorting out. A skilful workman, experienced in the treatment of these fabrics, will make several assortments, give boilings with soap, slight lye-boils of 0·5° to 1·0° Baumé, hand-rubbings, exposures on the green, but proceeds gently, so as not to destroy the fabrics. He ought to bring them to such a degree of whiteness that once they have received the third chemick no further operation should be necessary. (23) Third chemick, of 0·08° to 0·01° chlorometric degree; temperature, 25° C.; steep three to four hours; hand-wash; squeeze. (24) Sour, sulphuric acid, as first after chemick; and wash very carefully. The pieces are sent to be finished.

N.B.—Light hand-spun cambrics ought to be washed by hand, because in washing them by the wash wheels, washing machines, or wash mills, these very highly priced fabrics run the risk of being damaged. Especially is it the case when

the fabric has not been closely woven ; the threads approach each other in an uneven manner, and there is no longer any regularity between the warp and the weft. In order to wash the pieces the workman throws them into a tank of water. Holding them by one end he draws them out to their full length, then draws them back to himself and spins them out into the water again, repeating this manœuvre seven or eight times. After each lye-boil the fabrics are washed in the keir before being spread out on the green. For this purpose the lye is run off and hot water run on to the fabrics, then cold water, until it runs away clear and colourless. Experience has shown that this method of washing is quite sufficient for fabrics which easily take up water before putting them on the grass, but it would not be effectual after chemicking or souring. In the method of treatment prescribed, which yields very good results, the lyes are made from beginning to end with a mixture of caustic and carbonate alkali, 80 per cent of carbonate and 20 per cent of caustic alkali (soda). Another good method consists in making the lyes, which precede the chemick, an alkaline lye of that composition marking 1·8° Baumé, and those which follow the chemick with carbonate of soda three to four-tenths of a degree Baumé stronger than those given. The fabrics are boiled under the atmospheric pressure ; the circulation of the lye is effected by a column at the bottom of which is a steam injector. If the keirs be of wrought or cast iron, it is desirable to line them in the interior with wooden staves, so that the fabrics do not get worn by rubbing against the sides.

Chemick and Sour.—The use of sodium hypochlorite appears indispensable ; chloride of lime is not safe enough. The chemick steeps and sour steeps are given in wooden keirs at the temperature indicated, then the fabrics are packed in the bottom with a stick. The baths being feebler, they are run off after each operation, and the keirs filled with water for the first wash. It is important that the fabrics be well squeezed ; if not, the action of the chlorine and the acids, which are very weak, would be almost *nil*. If the fabrics have not been

squeezed, the strength of the sours and the chemick must be increased.

Sorting Out.—The assorting of the fabrics, especially towards the end, requires a very skilful and experienced workman. The number varies in consequence of the difference in the yarns which have been used in the weaving of the fabrics treated. The object of these assortments is to bring all the fabrics to the same degree of whiteness by gentler methods, so as not to injure them in the process.

Hand Washing.—The author tried whether the process of hand washing could be suppressed, and found that it could not. Without it the whites obtained were neither so bright nor so brilliant.

The Lime-Boiling of Linen Fabrics.—Certain linen fabrics can be bleached without it being necessary to lime-boil them. In that case, the finished goods are much softer, and smoother to the touch. Brown holland, for instance, which retains the tint of natural linen fibre, has undergone little or no bleaching treatment, merely a slight boil, in ordinary water, or a weak lye-boil with a solution of soda crystals, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, and, occasionally, a weak sour. The chief impurity in linen fabrics, that is partially removed in the lime-boiling, and still further removed in the soda-lye boiling of linen goods, is pectic acid, the chief ingredient of the brown colouring matter of linen. However, neither this colouring ingredient nor the pectic acid itself pre-exist in flax, but are elaborated by the chemical reactions, which follow from the putrefactive fermentation known as the retting of flax. From Kolb's researches it follows that, during the lime-boil, the milk of lime dissolves a certain amount of pectic acid, and that for every 100 parts so dissolved 48 parts of lime pass into the solution. Boiling with caustic and carbonated alkali eliminates a greater amount of pectic acid, but the caustic alkali (caustic soda) seems to dissolve more of the fatty impurities present, whilst the carbonated alkali (soda ash, soda crystals) seems to act more energetically on the green colouring principles. Linen yarns, therefore, which have been lye-boiled with carbonate of soda, still retaining

the greasy matter, are more soft to the touch than when lye-boiled with caustic alkali soda. The loss in weight which linen undergoes owing to the impurities extracted from it, by lime-boiling and boiling with caustic or with carbonated alkali, varies from 15 up to 36 per cent, that is, fully one-third of the weight of the linen may be lost in these operations. By merely boiling the linen with water alone for a week, it cedes as much as 18 per cent of its weight to the water. Before pectic acid can change from an insoluble to a soluble state it must first be converted into metapectic acid. The great difficulty in bleaching flax consists in the excessive amount of brown insoluble pectic matters present in the fibre, which cannot be eliminated by the action of bleaching powder alone, but require to be oxidized by exposure on grass, so as to remove some of the combined hydrogen. Neither bleaching powder nor exposure on grass on the bleaching green therefore destroys the insoluble pectic bodies constituting the colouring principles, which are merely converted into a form more readily attacked and dissolved by the alkalies. The bleaching action of chloride of lime, more especially on linen, is thus recognized to be due to the oxidizing powers of chlorine which produce—

1. An immediate bleaching of the textile fibre in consequence of the oxidation of the heterogeneous substances already prepared by several lye-boilings to be acted on by oxygen.

2. A partial oxidation of the colouring matter, which renders it soluble in alkalies. The colouring principle, which is regarded as an acid itself, produces the decomposition of the chloride of lime; for example it forms with it—

- (a) Insoluble pectates, which render the first chemicks and the first washings milky.

- (b) Soluble metapectates, which are carried away in the wash water.

- (c) A disengagement of free chlorine, which acts as a bleaching agent and transforms the pectates into metapectates.

It is acknowledged that this action is due to the oxidizing power of chlorine. It produces: (1) An immediate bleaching of

the textile fibre in consequence of the oxidation of the heterogeneous substances already prepared by several lye-boilings to be acted on by oxygen. (2) A partial oxidation of the colouring matter, which renders it soluble in alkalies. The colouring principle, which itself is regarded as an acid, produces the decomposition of the chloride of lime; for example it forms with it—(a) Insoluble pectates, which render the first chemicks and the first washings milky. (b) Soluble metapectates, which are carried away in the wash water. (c) A disengagement of free chlorine, which acts as a decolorizing agent and transforms the pectates into metapectates.

The fabrics which come out of chloride of lime (chemick) contain a lime soap (pectate of lime). If this pectate of lime be not decomposed by an acid bath (sour) and the fabrics in this condition lye-boiled, the stability of this lime soap will be increased and the result will be negative. Hypochlorite of soda does not present the same disadvantage, because the salts which it forms with colouring principles are more soluble.

The substance which gives steeped flax its peculiar tint is insoluble in boiling water, in acids, and in alkalies; but it possesses the property of dissolving in caustic or carbonated alkaline lyes by previous exposure to oxygen. Hemp is, in this respect, analogous to flax. The bleaching of both depends upon this action of oxygen, and upon the removal of the oxidized colouring principle, by means of an alkali. This process is effected generally by the influence of air in combination with light and moisture acting on the linen cloth laid upon the grass; but chlorine will to a certain extent if not completely effect the same object more expeditiously. In no case, however, is it possible to oxidize the colour completely at once, nor by chlorine, but there must be many alternate exposures to oxygen or chlorine, and alkali, before the flax becomes white. It is this circumstance alone which renders the bleaching of linen an apparently complicated business.

To bleach linen, that is, destroy the colouring principle, in one operation would involve the use of a chemick of such a strength as would destroy the fibre as well as the colour.

Unfortunately, too, if linen contains more impurities, the removal of which is requisite in bleaching, than cotton does, linen fibre is far more easily tendered by chemical agents than cotton.

Light Cambrics (Machine-spun).

These fabrics are not so fine and do not require to be handled so delicately; but as the warp and the weft are not tightly woven, care must be taken in the washing not to unweave the fabric. (1) Steep in hot water; hand-wash; squeeze. (2) First lime-boil or buck, in the proportion of 6 lb. of lime per 100 lb. of fabrics, six hours; boiling temperature; wash in the dash wheel; squeeze. (3) Sour, hydrochloric acid, 5 litres per cubic metre (5 gallons per 1000 gallons); temperature, 27° C. (80·6° F.); hand-wash; squeeze. (4) Second lye-boil, with salt of soda, 1·6° Baumé, with rosin soap; wash in the keir; squeeze. (5) Spread on the bleaching green for twenty-four hours. (6) Wash with soap on the rubbing boards, and third lye-boil, with salt of soda, at 1·6° Baumé; wash in keir; squeeze. (7) Spread on green for twenty-four hours. (8) Fourth lye-boil, with salt of soda, 1·6° Baumé, with rosin soap; wash in keir; squeeze. (9) Spread on green for twenty-four hours. (10) Assortment: first category—chemick; second category—lye-boil with salt of soda of 1·6° Baumé. (11) First chemick, at 0·15° chlorometric; temperature, 25° C.; steep six hours; hand-wash fine pieces, more common pieces to the wash mill; squeeze. (12) Sour, sulphuric acid in the proportion of 3 litres per cubic metre (3 gallons acid per 1000 gallons water); temperature, 27° C.; wash as after chemick; squeeze. (13) Boil with olein soap and lye-boil with a lye of 1·3° Baumé, made from a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent; wash in keir; squeeze. (14) Spread on green for twenty-four hours. (15) Second chemick, at 0·10° chlorometric; temperature, 25° C.; steep six hours; wash as after first chemick. (16) Sour as after first chemick. (17) Boil with olein soap; lye-boil with salt of soda at 1·3° Baumé; wash in keir. (18) Spread on the green for twenty-four hours. (19)

Sour, hydrochloric acid in proportion of 5 litres per cubic metre of water (5 gallons acid per 1000 gallons water); temperature, 27° C. (80·6° F.); hand-wash or wash mill; squeeze.

(20) Boil with olein soap and lye-boil with salt of soda at 1·3° Baumé; wash in keir; squeeze. (21) Assortment: first category—spread on green; second category—lye-boil with soda lye of 1·3° Baumé and spread on green. (22) Sour, hydrochloric acid in proportion of 5 litres per cubic metre of water; temperature, 27° C.; wash; dry. (23) Assortment. According to the degree of whiteness the fabrics are soap-boiled, lye-boiled, and spread on the green. It falls to the workmen entrusted with the treatment of the fabrics to regulate the number and the intensity of the treatments. A passage through the stocks, followed by a good washing with hot water, answers very well for the last operation before the final chemick. (24) Third chemick, 0·080° to 0·10° chlorometric; temperature, 25° C. (77° F.); steep four hours; wash; squeeze. (25) Sour, sulphuric acid, as after the first chemick; wash very carefully by hand or the dash wheel. Send to be finished.

The remarks made at the end of the treatment of the hand-spun yarn apply equally to the fabrics made from machine-spun yarn.

Lyes.—The lyes which precede the chemick may well be increased to 1·8° Baumé and those which follow it, of carbonate of soda of 1°, vary from 1·3° to 1·8° Baumé. To diminish the labour and economize soap, the boilings with soap preceding the lye-boilings may be suppressed and a little more soap added in the lyes. This modification does not diminish to any appreciable extent the perfection of the whiteness.

Chemicks and Sours.—If the chemick liquor be employed cold, and the fabrics be not squeezed, the baths may be made of the following strengths: first chemick, 0·60°, steep three hours; second chemick, 0·40°, steep three hours; third chemick, 0·30°, steep three hours. In the same way, if the sours be cold they are made of 0·5° Baumé.

Cambrics, Boiled Yarn Cambric Handkerchiefs, Household

*Linen (Blanc de Ménage).*¹—(1) Lime-boil ten hours with 10 per cent of lime on weight of fabrics; wash in stocks. (2) Sour, hydrochloric acid, 2° Baumé; temperature of bleaching room; wash in stocks. (3) Lye-boil ten hours, with addition of a lye of 3½° Baumé, made from a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent, with rosin soap; temperature, 112° C.; wash in keir. The fabrics are not taken out of the keir, and are lye-boiled a second time in the same way as the first; wash in stocks. (4) Spread on green two or three days. (5) Lye-boil ten hours with a lye of 2° Baumé, made from a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent, with rosin soap; temperature, 112° C.; wash in stocks. (6) Spread on green for two or three days. (7) Lye-boil as in (5). (8) Spread on green two or three days. (9) First chemick at 0·65° chlorometric; temperature of bleaching room; steep three hours; wash in stocks. (10) Sour, sulphuric acid, 1° Baumé; temperature of bleaching room; wash in stocks. (11) Scour with soap in wash mill or on rubbing boards; lye-boil six hours, with carbonate of soda, 1° Baumé; boiling temperature; wash in wash mill. (12) Spread on green for two days. (13) Second chemick and sour same as first. (14) Same as (11). (15) Third chemick and sour same as first. (16) Double washing in the dash wheel, after which the fabrics are sent to be finished. *N.B.*—The pieces which are not white enough are soaped or lye-boiled, or only chemicked and soured. In this process the fabrics are boiled with strong lyes before the chemick, and with weak lyes afterwards. A very bright white is thus obtained, and the soundness of the fabric is to a great extent preserved. The three chemicks have the same strength. Experience has shown that no mishap occurs by working in that way, and it is easier for the workman who prepares the chemick.

Cholet Cambrics and Cholet Handkerchiefs in Cholet White.

—(1) Lime-boil, ten hours, with 8 per cent of lime on weight of fabrics; boiling temperature; wash in stocks. Unbleached cloth and brown holland are put in the lime-boil dry; cream linen is first steeped in hot water and washed before lime-

boiling. (2) Sour, hydrochloric acid, 2° Baumé; temperature of bleaching room; steep six hours; wash in stocks. (3) Lye-boil, ten hours, with lye of 1·8° Baumé, and made from a mixture of caustic soda 20 per cent, soda ash 80 per cent, in proportion of 6 per cent of mixture on weight of fabrics; temperature, 110° C. (230° F.); wash in keir. The fabrics are not taken out, but are lye-boiled a second time in the same way as before, but with a slightly weaker lye, say 1·5° Baumé, and made in the proportion of 5 per cent of salt on the weight of fabrics; wash in stocks. (4) Spread on green for three days. (5) Lye-boil with a lye made from a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent, 1·5° Baumé, in proportion of 5 per cent of the mixed alkali on the weight of the fabrics; wash in stocks. (6) Spread on green for three days. (7) First chemick at 0·65 chlorometric degree; temperature of room; steep three hours; wash in stocks. (8) Sour, sulphuric acid at 1° Baumé; temperature of room; wash in stocks. (9) Wash with olein soap on the rubbing boards, etc.; lye-boil, eight hours, with sal soda at 1° Baumé, in proportion of 3 to 4 per cent of salt on weight of fabrics; boiling temperature; wash in stocks. (10) Spread on green for three days. (11) Second chemick and sour, same as first. (12) Assortment. Those which are not sufficiently white receive another scrubbing with soap on the rubbing boards, the others are lye-boiled directly with the former; lye-boil, six hours, with sal soda of 0·8° to 1° Baumé, with olein soap; boiling temperature; wash in stocks. (13) Spread on green for three days. (14) Third chemick, at 0·45° chlorometric; temperature of room; steep three hours; wash in stocks. (15) Sour, as after first chemick; double wash in stocks, or, better, one wash in stocks and one in dash wheel; send to be finished. If the fabrics be not white enough they are scoured with soap on the rubbing boards, boiled with weak lye, spread on the green, chemicked, and soured.

Fine Linens and Sheetings (Full White).—In this category are included fine white cambrics, Irish and Cambray linen. It is difficult to prescribe the number of processes to which they

should be subjected. That depends on the nature of the fabrics to be bleached and the quality of the yarn of which they are composed, and also upon the nature of the plant at the disposal of the bleacher. Thus open keirs do not act so energetically as closed keirs, in which the fabrics are lye-boiled at a higher temperature. A lye which circulates through the fabrics has more effect than a stationary lye. If very strong caustic lyes be used, fewer lye-boilings will be required than if they contained much carbonated and but little caustic alkali (soda). Practice has indicated the proportions in which the carbonate of soda and the caustic soda should be mixed, and the strength of the lyes made therefrom which are best adapted for the kind of fabric about to be treated. As a starting-point, reference should be made to what has been said in the examples of different processes to ascertain what method to pursue according to the results obtained. The following are the principles of the methods adopted in Ireland, and from which it is advisable not to depart.

1. *Chemicking of the Fabrics.*—The most important of all is not to chemick the fabrics until after they have reached a certain stage of brightness and whiteness, so that they may be at once completely bleached by the use of but a weak chemick. Experience has proved that if the fabrics are chemicked too soon—that is to say, before they have been sufficiently lye-boiled—it is almost impossible to bring them to a fine, beautiful white. The reason of this is not capable of being very satisfactorily explained; it may arise from the fact that the chlorine transforms certain bodies into more difficultly soluble substances, which the lye is unable to further dissolve in the subsequent operations. Experience has also shown that fabrics which have been chemicked no longer withstand the action of such strong lyes as previous thereto, and become more tender and attenuated under the action thereof. In winter spreading on the green does not contribute to the bleaching to the same extent as in summer, and its action is slower. For these reasons a very careful examination and assortment should be made, and all the

cloths which are not sufficiently white should be re-boiled and "grassed" as often as need be. The following figures, published by Dr. Andrews, of Belfast, which give a six years' summary of the operations of the Milltown Bleach Works, Bambridge, bring this fact out very prominently.

AVERAGE OF LYE-BOILS BEFORE AND AFTER THE CHEMICK FOR SIX YEARS, AND AVERAGE NUMBER OF DAYS' DURATION OF TREATMENT.

Months.	Number of Lye-boils before Chemick.	Number of Lye-boils after Chemick	Total Number of Lye-boils.	Number of Days under Treatment.
January - -	4'33	4'27	8'60	62'7
February - -	4'29	4'01	8'30	58'25
March - -	4'03	3'68	7'71	53'42
April - -	3'66	3'70	7'36	49'35
May - -	3'68	3'64	7'32	46'33
June - -	3'74	3'60	7'34	43
July - -	3'70	3'48	7'18	41
August - -	3'83	3'39	7'22	47
September - -	4'10	3'87	7'97	46'29
October - -	4'35	4'19	8'54	48'83
November - -	4'48	4'74	9'22	56'41
December - -	6'89	4'45	11'34	61'25

It therefore appears advisable in the winter months of November, December, January, and February to give heavy linen as a minimum five lye-boils and five spreadings on the green, and four lye-boils and four spreadings on the green during the rest of the year, and to give light fabrics four lye-boils and four spreadings on the green during winter, and three lye-boils and three spreadings on the green during summer. The lye-boils before the chemick should be made from a mixture of caustic and carbonated alkali—20 of caustic to 80 of carbonated alkali (soda). The strength of the lyes should gradually diminish in proportion as the bleaching process progresses.

The following strength¹ may be used :—

Lye-boil.	Summer.	Winter.
	Degrees Baumé.	Degrees Baumé.
1	2'5	2
2	2	2
3	2	1'5
4	1'5	1'5
5	1'5	

2. *Chemicking of Heavy Linens.*—There would appear to be no benefit to be derived from making an assortment before the chemick, so as to give a stronger chemick to the heavier linens. In fact the heavier linens are those which are most liable to tender under the treatment, the most difficult to bleach, and entail the oft-repeated application of gentle operations. It must no longer be believed that strong chemicks greatly promote the progress of bleaching. Chemicks of medium strength must be used, and these strengths have been determined by experience. The following strengths are recommended for hot and cold chemicks :—

Chemick.	Hot Chemick.		Cold Chemick.	
	Chlorometric Degree.	Duration.	Chlorometric Degree.	Duration.
1	0'20	7 hours.	0'60	3 hours.
2	0'15	7 hours.	0'40	3 hours.
3	0'15	6 hours.	0'30	3 hours.
4	0'10	4 hours.	0'25	3 hours.
5	0'10	4 hours.	0'20	2 hours.

It will be seen from this table that hot chemicks are much more energetic than cold. Care must be taken when steeping the goods in the chemick that they are thoroughly and equally impregnated throughout with the bleaching liquor, otherwise unequal bleaching will result. It would appear to be necessary to "reel" the fabrics into the first, second, and third chemick. Care must be taken not to multiply the chemicks too many times. Accordingly, before the fourth chemick, an experienced workman decides whether or not the fourth chemick will

render the fabrics white enough to be "finished" immediately afterwards. If he does not think so, he gives the fabrics a soaping and a weak lye-boil—two if need be—and he thus brings them so far forward in the bleaching that the fourth chemick is the last operation. A fifth chemick should be the exception.

3. *Carbonate of Soda Lyes.*—When the fabrics have been well lye-boiled before the chemick, the lyes which follow may very well be made from carbonate of soda (Solvay) without any addition of caustic soda. The advantage consists in being able to work with greater assurance of safety, and in having no fear that the soundness of the fabrics may be weakened. Certain bleachers, however, find that carbonate of soda alone does not forward the progress of the bleaching to the extent desired, and prefer to use a mixture of caustic and carbonated alkali from beginning to end of the operation. The strength of the lyes preferred by the author, whether consisting of carbonated alkali alone or of a mixture of caustic and carbonated alkali (sal soda), are as follows:—

Lye-boil.	Solvay Carbonate of Soda (Soda Ash).	20 per cent Caustic, 80 per cent Carbonate.
	Degrees Baumé.	Degrees Baumé.
After 1st Chemick - -	2	1'5
After 2nd Chemick - -	1'5	1'2
After 3rd Chemick - -	1	0'8
After 4th Chemick - -	1	0'6 to 0'7

4. *The Soap Bath.*—After the sours which follow the first, second, and even the third chemick, it is very advisable to wash the fabrics with soap on the rubbing boards or in the stocks. As this soaping follows the sour, it is advisable to add carbonate of soda and even caustic soda to the soap bath, so as to neutralize the acid and hinder the decomposition of the soap. This is the reason why every scouring with soap is followed by lye-boiling, however slight it may be. In fact as the soaping follows the acid, there is always a little decomposed soap, and neither washing in the ordinary way with

cold water nor even with hot water in the keir will remove the liberated fatty acid adhering to the fibres of the fabric. This precipitated fatty acid plus dark rosin will eventually, in dehydrating, yellow the fabrics if not removed. It must be saponified afresh by alkaline lye, however weak it may be. The fabrics are then washed and submitted to the final chemick, without spreading them on the green. This last exposure on the bleaching green has but little bleaching effect, and in bad seasons the fabrics are often soiled or damaged. Consequently, they are not spread on the green any further after the third chemick, and the bleaching process is completed in the works.

5. *Washing and Squeezing*.—Washing with the machine is the most economical, but it is to be feared that the water does not penetrate into the interior of the folds, and only washes on the surface. The washing which precedes the spreading on the green is best done in the wash mills (stocks) or wash wheels. In washing with the wash mills (stocks) the water penetrates into the interior of the fabrics, and is expressed by the compression of the hammer, but, as the fabrics are always in parcels, the dirt, such as dust, leaves, mud from the green, is not removed. In this case washing with the machine or the dash wheel must be resorted to. The wringing, which consists in squeezing or pressing out the wash water, is an excellent operation, because the fabrics are then more apt to benefit to the full extent by the succeeding process.

If hot chemicks and hot sours be used of the strengths previously indicated, the wash water must unquestionably be wrung out, or at least allowed to drain or drip off. The strength of these chemicks and sours is very weak; nevertheless, they are sufficiently strong if the fabrics be well wrung, but they are not so if the fabrics are impregnated with water.

6. *Inspection*.—When valuable linen is being bleached it is advisable to stretch it from time to time during the whole course of the bleaching operations. A workman is deputed to examine it, and to report any damage which he may find.

The cause is at once sought, and the damage prevented from spreading.

These observations have led to the adoption of the following course of operation: (1) Lime-boil; wash; sour; wash. (2) Lye-boil with a mixture of caustic and carbonated alkali; wash. (3) Spread on green. (4) Lye-boil with a mixture of caustic and carbonated alkali; wash. (5) Spread on green. (6) Lye-boil with a mixture of caustic and carbonated alkali; wash. (7) Spread on green. (8) Assortment: First category—To chemick; Second category—Lye-boil with salt of soda; wash; spread on green. (9) First chemick; wash; sour; wash. (10) Scour with soap on rubbing boards; lye-boil with carbonate of soda or with a mixture of caustic and carbonated alkali; wash. (11) Spread on green. (12) Second chemick; wash; sour; wash. (13) Same as (10). (14) Spread on green. (15) Third chemick; wash; sour; wash. (16) Assortment. Those fabrics white enough are sent to be finished; the others are further treated as follows: (17) Wash in stocks with soap; slightly lye-boil; wash. They are then examined to ascertain if fit for fourth chemick. If not, they are given a fresh rubbing with soap and a fresh lye-boil. (18) Fourth chemick; wash; sour; wash. (19) If the fabrics are not even now white enough to be finished, they are given a scouring with soap and a lye-boil, followed by washing. (20) Fifth chemick; wash; sour; wash.

Coarse North of France (du Nord) or Normandy Sheetting, Woven from Cream Yarn.—These linens are much more delicate to bleach than finer fabrics, because they are more impervious to chemical reagents, and also because it is, moreover, very difficult to wash them thoroughly after each operation. They are therefore treated with weak lyes and long exposures on the green. By the following methods the fabrics preserve their soundness to a great extent, but by giving them very thorough washing they may be treated more energetically and yet be sound enough, whilst at the same time a prettier white is obtained.

Ordinary White (Blanc Ordinaire).—(1) Steep in hot water

for twelve to twenty-four hours; wash in machine. (2) First lye-boil, eight hours, with a mixture of caustic and carbonated alkali in proportion of 3 per cent on weight of fabrics; the lye marks 0.8° to 1° Baumé; temperature not to exceed 90° to 95° C.; wash in machine. (3) Spread on green for five or six days. (4) Second lye-boil, with a mixture of caustic and carbonated alkali in proportion of 2 per cent of mixture on weight of fabrics; operation conducted same as in first lye-boil; wash in machine. (5) Spread on green five days. (6) First chemick, at 0.75° chlorometric; temperature of bleach works; steep four to five hours. In winter it is advisable to heat the chemick to 20° C. (68° F.); wash in machine. (7) Sour, sulphuric acid, 1° Baumé; temperature of the bleach works; wash in machine. (8) Lye-boil six hours with a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent, in proportion of $1\frac{1}{2}$ per cent on weight of fabrics; wash in machine. (9) Spread on green five days. (10) Second chemick, at 0.75° chlorometric; steep four hours; wash in machine. (11) Sour, sulphuric acid, 0.5° Baumé; temperature of bleach works; wash in machine. (12) Lye-boil six hours with a mixture of caustic 20 per cent, and carbonated alkali 80 per cent, in proportion of 1 per cent of mixture on weight of fabrics; temperature, 60° C. (140° F.). (13) Third chemick, at 0.5° chlorometric strength; temperature of the bleach works; wash in machine. (14) Sour, sulphuric acid, at 0.5° Baumé; temperature of the works; wash in machine. (15) Soap, boil six hours with 3 parts by weight of soap and 2 parts by weight of salt of soda per 1000 parts by weight of fabrics; temperature, 60° C. A little indigo is put in this lye so as to impart a bluish tint to the fabrics, a tint which they retain much better than that of the blue applied to them in the finishing process. Wash in stocks; send to be finished.

Fine White (Beau Blanc).—The operations are the same as those for ordinary linen white. In addition, the fabrics receive after the third chemick a lye-boil and an exposure on the green, and a fourth chemick.

Three-quarters White.—Same operations as for ordinary

linen white, but no further than ~~the~~ sour after the second chemick, when they receive the final soaping and are sent to be finished.

Half White (Cream).—These cloths receive a chemick at 1° chlorometric strength, into which they are put dry as they come from the warehouse. Steep three to four hours; wash in stocks; give a second chemick at 0·75° chlorometric strength; sour, and give the final soaping, with blue, before sending to be finished.

Sponging (Décatissage).—Boil with soap lye; wash and send to be finished.

Fine Cambric or Cholet Handkerchiefs with Coloured Border, Woven from Half White Yarn.—(1) Steeping. *Grey Wash.*—To strip the fabrics of surface impurities they are passed through a double washing machine. The tank of the first machine contains hot water at 50° C., whilst cold water circulates in the other. (2) Lye-boil in the double washing machine. The two tanks contain lye of 1° Baumé kept at a temperature of 50° C. Wash in washing machine. (3) Spread on green for two days. (4) Lye-boil six hours in keir, with carbonate of soda, 2° Baumé; temperature, 65° C. (149° F.); or lye-boil six hours with carbonate of soda, 1° Baumé; temperature, 75° to 80° C. (167° to 176° F.); wash in washing machine or wash mills. (5) Spread on green for two days. (6) Repeat the lye-boils and exposures on the green as many times as are required to bring the fabrics to the degree of whiteness aimed at, and as far as the durability of the fabric will permit of this being done. In order to produce a full white the handkerchiefs receive five lye-boils in the keir and six spreadings on the green before being chemicked. The operations are conducted so as to give the fabrics all the necessary lye-boilings before the chemick, which ought to be single, because once they have been chemicked the colour is much more easily attacked by the alkaline lye. (7) Chemick, 0·20° to 0·25° chlorometric strength; temperature of works; steep three hours; reel twice in the tank; wash twice in the washing machine or wash mills. (8) Pass through oxalic or acetic acid in the double washing

machine. The tank of the first machine contains acid, whilst water in the other is kept constantly renewed. This first washing should be followed by a second in the washing machine or in the dash wheels or wash mills. (9) Assortment. After the chemick the fabrics are assorted. Those which are white enough are sent to be finished, whilst the others receive a slight lye-boil, a spread on the green, and a chemick at 0.15° chlorometric strength.

The double washing machine referred to is described in chapter III. It is very convenient for treating with feeble lyes. A steam-pipe is then placed under the false bottom to heat the water or the lye. As a washing machine it enables two washings to be given to the goods simultaneously without extra labour. It is well to commence by treating the fabrics with alkaline lye in the washing machine, because the colour then discharges itself without soiling the inner margin of the fabrics, as would be the case if the first lye-boil was given in the ordinary keir. Coloured fabrics may be lye-boiled in a keir where the circulation of the lye is effected by a Koerting injector. But the circulation must be intermittent, so as not to exceed a temperature of 65° C. (149° F.). The fabrics should not be too strongly packed in the keir; the lye is run in first, and the fabrics are afterwards piled therein by the aid of a stick. This mode of packing has the inconvenience of only allowing a small quantity of fabrics to be put into a keir at a time. It is better to use a keir where the circulation of the lye is effected by a centrifugal pump. As the circulation in that case is made independently of the steam introduced for heating purposes, it may be made as energetic as desired, whilst at the same time the lye is maintained at a constant temperature. In this case the pieces are piled in the keir and lashed or pressed down, and the lye is then run on them from above. Thus in a keir of the same capacity a great many more pieces may be stowed than in the former case. For coloured fabrics carbonate of soda alone is generally used, but if very good colours are to be treated a little caustic soda and soap may be used. If the colours have but little resistance the

lyes should not be too strong nor the temperature too high. The author has observed that a lye of 1° Baumé, heated to 80° C., produced the same effect as a lye of 65° C. and 2° Baumé. The circulation of the lye is made by a centrifugal pump. In summer the sun discharges certain colours. It is advisable to take them in when the sun is too hot, or to cover them well with other fabrics. When the fabrics come off the green soiled with mud they must be washed before being lye-boiled, because the lye bakes the mud, and it is much more difficult to remove afterwards. After the chemick the fabrics are not soured with sulphuric or hydrochloric acid for fear of weakening the colour; only a weak acid is used, such as oxalic acid.

Handkerchiefs with Coloured Borders (another method).—(1) Steep in warm water, 25° C.; wash. (2) Steep in soap bath for two hours at a temperature of 25° C. (3) Spread on green two days. (4) Lye-boil six hours with carbonate of soda, 2° Baumé; temperature, 65° C.; wash. (5) Spread on green two days. (6) Steep in a bath of soap; wash. (7) Spread on green two days. (8) Lye-boil six hours with carbonate of soda at 2° Baumé; temperature, 65° C.; wash. (9) Spread on green two days. (10) Assortment. Put on one side the fabrics white enough to go to the chemick, and send the others to be lye-boiled, and spread on the green. (11) Chemick, chlorometric strength 0·2° to 0·5°; temperature of the works; steep three hours; reel twice; wash. (12) Sour, oxalic acid, as indicated in previous treatment. Souring with oxalic acid may be dispensed with if the chemick has been followed by thorough and effectual washing. (13) Assortment. Place on one side the fabrics which are white enough to be finished, and on the other those which require a lye-boil, a spread out on the green, and a chemick.

The soap bath for steeping is made in the proportion of 3½ kilogrammes of Marseilles soap per cubic metre of water, 3½ lb. per 100 gallons. The same bath may be used two or three weeks; it is run away when it smells too badly. Every five days 500 grammes of soap are added to replace the soap

absorbed by the fabrics, say $\frac{1}{2}$ lb. per 100 gallons. The temperature should not exceed 25° C. (77° F.), so that the soap does not attack the colours. So as to preserve the colours as far as possible, no soap is added to the lye. If the colours are good, the use of soap, provided it be not caustic, will not be the cause of any danger, and will help to render the action of the lye more energetic. If lye be not circulated by a pump, and is thus very slow, the fabrics must be so stowed in the lye as not to be crushed, otherwise the result of the lye-boiling will be very unequal.

Linen Bleaching with Lye-Boiling in Mather's Keir.—The following examples of processes, using Mather's keir, were experimented with by Tailfer, and yielded good results. He made many experiments and has seen many experiments made, some successful, some barren, and it is as a result of these experiments that he has been able to prescribe the processes detailed further on. As to the other operations, such as washing, squeezing, chemicking, souring, he indicates those which he gives to the fabrics; they may be modified according to the particular installation of each bleach works, and according to the methods adopted therein. The washing in the keir is very important, above all after the caustic soda lye; it frees the fabrics from a part of the soda. A single washing with 4000 litres (880 gallons) of water may do, but two are preferable. It is useful to have a reservoir tank in which the water is heated beforehand, because hot water cleanses the fabrics better. Two washings are prescribed after the lye-boils, the one with the roller washing machine, the other with the stocks or dash wheel. Although a single washing may often suffice, the author advises two, because the durability imparted to the fabrics will largely compensate for the extra labour.

Fine White. Cambric Muslins and Handkerchiefs.—(1) Steep from twelve to twenty-four hours; wash in roller washing machine, in dash wheel, or stocks; squeeze. (2) First lye-boil, six hours, Mather's keir; caustic soda of 1.1° Baumé in summer and 1.4° Baumé in winter; temperature,

116° C.; wash in roller washing machine and in stocks. (3) Bleaching green, two days. (4) Sour, hydrochloric acid 0·5° Baumé; temperature, 27° C. (80·6° F.); wash in stocks; squeeze. (5) Second lye-boil, Mather's keir, same as previously. (6) Bleaching green, two days. (7) Third lye-boil, six hours, Mather's keir; salt of soda, 1·5° Baumé; temperature, 116° C. (240·8° F.); wash in roller washing machine and in stocks. (8) Bleaching green, two days. (9) Assortment: first category—chemick; second category—boil with salt of soda, 1·5° Baumé, in small keirs. (10) First chemick, at 0·20° chlorometric strength; temperature, 25° C. (77° F.); steep seven hours; reel; wash in stocks; squeeze. (11) Sour, sulphuric acid of 0·5° Baumé; temperature, 27° C. (80·6° F.); wash in stocks; squeeze. (12) Scour with soap on rubbing boards. (13) Fourth lye-boil, four hours, Mather's keir, with carbonate of soda lye of 2° Baumé; temperature, 105° C. (221° F.); wash in roller washing machine. (14) Bleaching green for two days. (15) Second chemick, at 0·15° chlorometric strength; temperature, 25° C. (77° F.); steep seven hours; reel; wash in stocks; squeeze. (16) Sour, sulphuric acid of 0·5° Baumé; temperature, 27° C. (80·6° F.); wash in stocks; squeeze. (17) Scour with soap on rubbing boards. (18) Fifth lye-boil, four hours, Mather's keir, with carbonate of soda lye of 1·5° Baumé; temperature, 105° C. (221° F.); wash in roller washing machine; squeeze. (19) Bleaching green, two days. (20) Third chemick, of 0·10° to 0·15° chlorometric strength; temperature, 25° C. (77° F.); steep six hours; reel; wash in stocks; squeeze. (21) Sour, sulphuric acid of 0·5° Baumé; temperature, 27° C. (80·6° F.); wash in stocks; squeeze. (22) Assortment: first category—finish; second category—fourth chemick, sour and finish; third category—scour with soft soap in stocks or on rubbing boards, boil with carbonate of soda of 1° Baumé, fourth chemick, sour and finish. (23) Fourth chemick, at 0·10° chlorometric strength; temperature, 20° C. (68° F.); steep four hours; wash in stocks; squeeze. (24) Sour, hydrochloric acid of 0·25° Baumé; temperature, 27° C. (80·6° F.); wash in stocks; squeeze. A sour

is the last operation before despatching to be finished. After the third chemick it is the duty of the workman entrusted with the assortment to decide what further operations are necessary to complete the bleaching. Exposure on the bleaching green will also be useful, provided always that the fabrics run no risk of being soiled whilst there. In any case the fabrics must be lye-boiled before the fourth chemick. As soon as this latter operation is done there is no need to resort to others.

Household White.—Cambric Muslins and Handkerchiefs.—

(1) Steep; wash; squeeze. (2) First lye-boil, six hours, Mather's keir, with caustic soda lye of $1\cdot5^{\circ}$ Baumé; temperature, 116° C. ($240\cdot8^{\circ}$ F.); wash in roller washing machine and stocks. (3) Bleaching green, two days. (4) Sour, hydrochloric acid of $0\cdot5$ Baumé; temperature, 27° C. ($80\cdot6^{\circ}$ F.); wash in stocks; squeeze. (5) Second lye-boil, Mather's keir, in the same conditions as the first. (6) Bleaching green, two days. (7) First chemick, of $0\cdot35^{\circ}$ chlorometric strength; temperature, 25° C.; steep five hours; reel; wash in stocks; squeeze. (8) Sour, sulphuric acid of $0\cdot5^{\circ}$ Baumé; temperature, 27° C.; wash in stocks; squeeze. (9) Scour with soap on rubbing boards. (10) Third lye-boil, four hours, Mather's keir; carbonate of soda lye 2° Baumé, or salt of soda of $1\cdot5^{\circ}$ Baumé; temperature of boiling, 105° C. (221° F.); wash in roller washing machine. (11) Bleaching green, two days. (12) Second chemick, of $0\cdot30^{\circ}$ chlorometric strength; temperature, 25° C. (77° F.); steep five hours; reel; wash in stocks; squeeze. (13) Sour, as after first chemick; wash in stocks; squeeze. (14) Assortment: first category—finish; second category—chemick at $0\cdot20^{\circ}$ chlorometric strength; steep four hours; sour and finish; third category—scour with soap and lye-boil with carbonate of soda at 2° Baumé; chemick at $0\cdot2^{\circ}$ chlorometric strength; steep four hours; sour; finish.

Cholet White (blanc de Cholet).—Muslins and Handkerchiefs.

—(1) Steep; wash; squeeze. (2) Boil ten hours with milk of lime in proportion of 10 per cent of quicklime on weight of fabrics; wash in roller washing machine or in stocks. (3) Sour at $0\cdot5^{\circ}$ Baumé; temperature, 27° C. ($80\cdot6^{\circ}$ F.); wash.

(4) First lye-boil, six hours, Mather's keir; caustic soda lye of $1\cdot4^{\circ}$ Baumé; temperature, 116° C. ($240\cdot8^{\circ}$ F.); wash in roller washing machine and in stocks. (5) Bleaching green, two or three days. (6) Second lye-boil, six hours, Mather's keir, with a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent; soda lye, $1\cdot5^{\circ}$ Baumé; temperature, 116° C. ($240\cdot8^{\circ}$ F.); wash in roller washing machine and in stocks. (7) Bleaching green, two days. (8) First chemick, of $0\cdot25^{\circ}$ chlorometric strength; temperature, 25° C.; steep six hours; reel; wash in stocks; squeeze. (9) Sour at $0\cdot5^{\circ}$ Baumé; temperature, 27° C. ($80\cdot6^{\circ}$ F.); wash in stocks; squeeze. (10) Scour with soap on rubbing boards. (11) Third lye-boil, four hours, Mather's keir, with sal soda lye at 1° Baumé; temperature, 105° C. (221° F.); wash. (12) Bleaching green, two days. (13) Second chemick, of $0\cdot20^{\circ}$ chlorometric strength; temperature, 25° C. (77° F.); steep six hours; reel; wash in stocks; squeeze. (14) Sour, same as after first chemick; wash; squeeze. (15) Assortment: first category—finish; second category—scour, chemick, sour, finish; third category—scour, lye-boil with a lye of 1° Baumé made from a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent; sour and finish. *N.B.*—The last chemick of $0\cdot15^{\circ}$ chlorometric strength; temperature, 25° C.; steep five hours.

Fine du Nord Linen and Irish Linen.—(1) Steep from twelve to twenty-four hours; wash; squeeze. (2) First lye-boil, six hours, Mather's keir, with caustic soda lye of $1\cdot2^{\circ}$ Baumé; temperature, 116° C. ($240\cdot8^{\circ}$ F.); wash in roller washing machine and in stocks. (3) Bleaching green, four days. (4) Sour, hydrochloric acid of $0\cdot5^{\circ}$ Baumé; wash in stocks; squeeze. (5) Second lye-boil, Mather's keir, same as first. (6) Bleaching green, four days. (7) Third lye-boil, six hours, Mather's keir, with lye of 2° Baumé made from a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent; temperature, 116° C. ($240\cdot8^{\circ}$ F.); wash in roller washing machine or in stocks. (8) Bleaching green, four days. (9) Assortment: first category—chemick; second category—lye-boil with sal soda lye of $1\cdot5^{\circ}$ Baumé. (10) First chemick,

of 0.20° chlorometric strength; temperature, 25° C. (77° F.); steep seven hours; reel; wash in stocks; squeeze. (11) Sour, sulphuric acid, 0.5° Baumé; temperature, 27° C.; wash in stocks; squeeze. (12) Scour with soap on rubbing boards. (13) Fourth lye-boil, four hours, Mather's keir, with carbonate of soda lye of 2.0° Baumé; temperature, 105° C. (221° F.); wash in roller washing machine. (14) Bleaching green, four days. (15) Second chemick, of 0.15° chlorometric strength; temperature, 25° C. (77° F.); steep seven hours; reel; wash in stocks; squeeze. (16) Sour, sulphuric acid of 0.5° Baumé; temperature, 27° C. (80.6° F.); wash in stocks; squeeze. (17) Scour with soap on rubbing boards. (18) Fifth lye-boil, four hours, Mather's keir, with carbonate of soda lye of 1.5° Baumé; temperature, 105° C. (221° F.); wash in roller washing machine. (19) Bleaching green, four days. (20) Third chemick, of 0.10° chlorometric strength; temperature, 25° C. (77° F.); steep six hours; reel; wash in stocks; squeeze. (21) Sour, sulphuric acid of 0.5° Baumé; temperature, 27° C. (80.6° F.); wash in stocks; squeeze. Starting from here it is the duty of the workman entrusted with the assortment to decide the number of operations necessary to arrive at the proper degree of whiteness, having due regard to the durability of the fabrics. It is therefore necessary to make a selection from the following operations. (22) Scour with soap on the rubbing boards. (23) Lye-boil with carbonate of soda lye of 0.7° to 1.0° Baumé. (24) Bleaching green, two days. (25) Scour or light lye-boil. (26) Chemick of 0.10° chlorometric strength; temperature, 25° C. (77° F.); steep four hours; wash in stocks. (27) Sour, hydrochloric acid of 0.25° Baumé; temperature, 20° C. (68° F.); wash in stocks and wash wheels. Finish. Before the first chemick, in bad weather, it is very useful to give the fabrics a fourth lye-boil in Mather's keir, with a lye of 2° Baumé made from a mixture of caustic soda 20 per cent, carbonate of soda 80 per cent. It must not be decided beforehand to give a certain number of lye-boilings and exposures on the bleaching green before the chemick, but to give the linen fabrics the number of lye-boils required to prepare them for

the chemick. This depends on the nature of the fabrics and the season. Irish linens demand a more decided white than du Nord linen. The treatment of the former commences with a lime-boil, followed by a hydrochloric acid sour. If the linens are woven with cream yarn they must receive a steep, followed by a wash, before being lime-boiled. Linen cloths are more difficult to bleach than handkerchiefs and fine linen, as they are more closely woven; they must be treated with weaker lyes, etc., and these are repeated more often, care being taken that the washings are thorough, the soundness of the fabric being ascertained from time to time as the bleaching process progresses. Heavy, coarse, tightly woven linen cloths are more easily tendered than fine linens; they must be treated with weaker lyes, and it is prudent not to attempt to bleach them too far at the expense of soundness and durability. The process given indicates the maximum number of treatments to be given in winter. In summer the number of lye-boils and their strength is diminished.

Bleaching Linen and other Vegetable Fibres.—According to a French patent linen, cotton jute and varied goods can be bleached by sodium peroxide thus: A lye is made by mixing 8 parts of caustic soda, 1 part of sodium silicate and 1 part of sodium peroxide, 1 part of the mixture being dissolved slowly and in small portions in 150 parts of cold water. The resulting lye is poured over 25 parts by weight of linen goods in a bowking keir, which is then filled up with water, closed and gently warmed for three to four hours. This causes a gradual liberation of oxide from the peroxide, the impurities in the linen fibres being thereby oxidized and bleached, whilst the alkali saponifies any fatty matters present. Finally the goods are washed and chemicked with bleaching powder if necessary. This method is said to give better results than the older processes.

Bleaching Linen with Hydrogen Peroxide. Ubecini's Process.—If bleaching by hydrogen peroxide be more expensive than exposure on the bleaching green, the result is not equal to that obtained on the green. The better result obtained on

the grass is to some extent due to the ozone present in the air. The sequence of the treatments in the Ubicini process is: Steeping the linen, washing, liming, 2 to 3 per cent on weight of fabrics, souring with hydrochloric acid, washing in a 2 per cent lye of carbonate of soda, 0.5 per cent of rosin, soaping for three hours at 122° F., washing for three hours and treating with hydrogen peroxide at 120° (140° F.), the goods being turned at frequent intervals. A treatment with hydrochloric acid completes the process.

CHAPTER XIX.

BLEACHING OF COTTON FABRICS.

COTTONS. — *Dry and Swanskin Piqué's* — *Calicoes, Jaconets, Nansouks*—*Embroidery*—*Piqué's with Stripes of Different Colours*—*Spongy Fabrics with Coloured Borders*—*Spongy Fabrics with Red Borders* — *Spongy Fabrics without Coloured Borders.*

Piqué's Secs and Piqué's Molletonnés.—(1) Lime-boil, ten hours, 10 per cent of lime on weight of fabrics; boiling temperature; wash in washing machine. (2) Sour, hydrochloric acid 2° Baumé; temperature of works; steep at least six hours; wash in washing machine. (3) Lye-boil ten hours with sal soda at 3° Baumé, in proportion of 10 per cent of salt on weight of fabrics, with the addition of rosin soap; temperature, 110° C.; wash in the keir, followed by a second lye-boil under the same conditions as the first; wash in washing machine. (4) First chemick, chlorometric strength 1·0° or 0·318 available chlorine per cent; temperature of the works; steep three hours; wash in washing machine. (5) Sour, mixture of 7 litres of sulphuric acid with 4 litres, 7 gallons and 4 gallons per 100 gallons of hydrochloric acid per cubic metre of water, 0·8° Baumé, six hours; temperature of works, wash in washing machine. (6) Lye-boil eight hours with carbonate of soda of 1·5° Baumé, made in the proportion of 5 per cent of carbonate of soda and 1 per cent of Marseilles soap on the weight of fabrics; temperature, 110° C.; wash in washing machine. (7) Second chemick, same as first; wash in washing machine. (8) Sour, same as after first chemick. The fabrics are then washed twice in washing machine and sent to be finished. This
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method gives a very beautiful white, whilst at the same time the fabrics retain much of their strength. Lye-boiling is done in closed keirs, under pressure, and the circulation is effected by a centrifugal pump throughout the whole of the lye-boil. The fabrics are chemicked and soured in such a manner that they are thoroughly impregnated throughout their entire mass. Whilst the fabrics are being delivered into the chemicking and souring tanks, the chemick or the sour is pumped in at the same time. A man, shod with india-rubber boots, tramps down the fabrics. The fabrics may also be steeped by immersing them in the liquid by means of a stick. In the latter case a much smaller quantity can be packed in the same tank.

Calicoes, Jaconets, Nansouks.—(1) Steep in hot water; wash. (2) First lye-boil, ten hours, with sal soda, 2° Baumé, with olein soap; temperature, 110° C.; wash. (3) Second lye-boil, same as first; wash in keir. (4) Assortment: first assortment—chemick; second assortment—lye-boil as before. (5) First chemick, chlorometric strength of 0·15° to 0·20°; temperature, 25° C. (77° F.); steep five to six hours; wash and wring. (6) Sour, 3 litres of acid to 1 cubic metre of water, 3 gallons to 1000 gallons; temperature, 27° C. (80·6° F.); wash and squeeze. (7) Lye-boil, six hours, with carbonate of soda, at 2° Baumé, with Marseilles or olein soap; boiling temperature; wash in keir. (8) Second chemick, chlorometric strength 0·15°; temperature, 25° C.; steep five to six hours; wash; squeeze. (9) Sour, sulphuric acid, same as after first chemick. (10) Assortment: first assortment—finish; second assortment—lye-boil, chemick, finish. The method of washing has not been given after each operation. Washing in the washing machine is more rapid and economical than by the wash wheels; it has the disadvantage of not penetrating the fibre and opening the grains. The author therefore advises, wherever practicable, to wash by the dash wheel. The chemicks and sours indicated require to be warmed, and to produce a good effect the fabrics should have previously been well squeezed. If cold chemicks and

sours be used, and the fabrics be not squeezed, they should be of the following chlorometric strength: First chemick, 0.65° ; second chemick, 0.50° ; third chemick, 0.30° . The sours are made of density of 0.7° Baumé. It is not necessary to wash the fabrics by the machine as they come from the lye to go to the chemick; a wash in the keir suffices. If the fabrics retain a little lye it renders the chemick a little more alkaline, and its bleaching action slower. The yellow tint of the fabrics as they come from the chemick disappears in the sour.

Embroidery.—(1) Steep in hot water; wash in wash wheel; wring. (2) Lime-boil eight hours in proportion of 6 per cent of lime on weight of fabrics; boiling temperature; wash; wring. (3) Sour, hydrochloric acid, 0.5° Baumé; temperature, 27° C. (80.6° F.); wash; wring. (4) Lye-boil, eight hours, with sal soda (caustic and carbonated alkali), 2° Baumé, with olein soap; temperature, 110° C. (230° F.); wash; wring. (5) Wash the strongest and darkest pieces in the stocks with soap; send the others direct to the lye-boil. Lye-boil with sal soda the same way as in No. 4; wash in keir. (6) Assortment: first assortment—chemick; second assortment—wash in stocks with soap, lye-boil with salt of soda 1.5° Baumé, chemick. (7) First chemick, chlorometric strength 0.2° ; temperature, 25° C. (77° F.); steep five hours; wash; wring. (8) Sour, sulphuric acid 3 litres per cubic metre, 3 gallons per 1000 gallons; temperature, 27° C.; wash; wring. (9) Soap in stocks with olein soap; lye-boil, eight hours, with carbonate of soda, 2° Baumé (2.8° Tw.); boiling temperature; wash in keir. (10) Second chemick, chlorometric strength, 0.15° ; temperature, 25° C. (77° F.); steep four hours; wash; wring. (11) Sour as after first chemick; wash; wring. (12) Assortment: first assortment—finish; second assortment—chemick; third assortment—lye-boil with carbonate of soda at 1.5° Baumé, and chemick. (13) Third chemick, chlorometric strength 0.1° ; temperature, 25° C. (77° F.); wash; wring. All the washings are done by the dash wheel; if the fabrics be too fine they are hand-washed. The chemicks and sours indicated are heated. If applied in the cold, the operations

must be conducted as prescribed in remark following the treatment of calicoes (pp. 280-1).

Piqués with Stripes of Different Colours.—(1) Steep in tepid water; wash. (2) Lye-boil three or four times with carbonate of soda; wash between each lye-boil. If the colours be delicate the pieces are reeled in the lye to prevent the colour from depositing. (3) First chemick, chlorometric strength 0.3° ; temperature of works; steep three hours; reel; wash. (4) Second chemick at 0.2° chlorometric strength; temperature of the workshop; steep three hours; reel; double wash and send to be finished. The strength of the lyes and sours ought to be proportioned to the resistance of the colour to be treated. Experience alone will guide the bleacher and instruct him as to what operations are suitable for certain colours and not for others. The lyes are carbonate of soda lyes of 2° Baumé. The temperature varies from 65° to 70° C. The keirs are surmounted by a winder or reel, and the pieces are successively rolled round this reel or winder, and then unrolled into the lye. In this manner the fabrics are continually on the move, and if the colour be dissolved out it is carried away by the lye and does not stain the fabrics.¹

Spongy Fabrics with Borders of Various Colours.—The treatment of these depends on the resistance of the colours. They are treated like colour-striped piqués. The following operations are generally sufficient. (1) Steeping by passing the fabrics through the double washing machine. The tank of the first machine contains water heated to 50° , and the

¹ The common process of bleaching pulicates, into which permanent colours are woven, is to wash the dressing or starch well out in cold water; to boil them gently in soap, and, after again washing, to immerse them in a moderately strong solution of potassium hypochlorite, and this process is followed until the white is good; they are then soured in dilute sulphuric acid. If the goods are attended to in a proper manner, the colours, in place of being impaired, will be found greatly improved, and to have acquired a delicacy of tint which no other process can impart to them. Pulicates, or gingham, which have been woven along with yarn which has been previously bleached, are first freed by washing from the starch or dressing; they are then washed, or slightly boiled with soap; after which, they are completely rinsed in pure spring water, and then soured. (Ure.)

water in the second tank is cold ~~water~~ unceasingly renewed, i.e. ingress and egress taps are kept running. (2) Lye-boil once or twice in the double washing machine, with carbonate of soda lye of 1° to 2° Baumé, 1·4° to 2·8° Tw., at a temperature of 65° C. (149° F.). (3) First chemick, chlorometric strength 0·30°; temperature that of works; steep two to three hours; reel; wash in washing machine. (4) Second chemick, chlorometric strength 0·20°; temperature that of works; steep two to three hours; reel; double wash in washing machine. (5) Pass to blueing in double washing machine as indicated for spongy fabrics with red borders.

Spongy Fabrics with Red Borders (Napkins, Towels, Bath Towels, etc.).—This treatment is not recommended to be applied to fabrics the colour of which is not fast and persistent; but red is not altered by a slightly caustic lye. (1) Steep in warm water of 30° C. (86° F.); wash in washing machine. (2) Lye-boil, eight hours, with a mixture of 20 per cent caustic soda, 70 per cent strength, and 80 per cent carbonate of soda, 1·2° Baumé (1·62 Tw.); boiling temperature; wash in washing machine. (3) Same as (2). (4) First chemick, chlorometric strength 0·60; temperature of works; steep three hours; reel twice; wash in washing machine. (5) Sour with sulphuric acid, 2 litres to the cubic metre of water, 2 gallons per 1000 gallons in double washing machine. The tank of the first machine contains the acid, and the second the water, which is continually renewed. (6) Second chemick, chlorometric strength 0·50°; temperature of works; steep three hours; wash twice with washing machine. (7) The fabrics are blued without being finished. For this purpose a washing machine the tank of which contains the blue is very convenient. A little soap is added to impart softness to the fabrics.

Spongy Fabrics without Coloured Borders.—These fabrics are treated in the same way as those with a coloured border, but as discoloration is not to be feared the lye may be made of the usual mixture of caustic and carbonate alkali of 2° Baumé instead of 1·2° Baumé; then after the chemick they are soured in the ordinary way. Moreover, these fabrics are

very easily bleached, only care must be taken that they are not spotted by the lye; this happens when they are pressed too tightly in the keir.

Example of Cotton Bleaching with Mather's Keir—Calicoes, Piqué's Secs, and Swanskin Piqué's.—(1) Boil six hours with milk of lime in proportion of 10 per cent of lime on the weight of the fabrics; wash in roller washing machine. (2) Sour, hydrochloric acid of 0.5° Baumé; temperature, 27° C. (80.6° F.); wash in washing machine. (3) First lye-boil, seven hours, Mather's keir, with caustic soda lye of 2.2° Baumé; temperature, 116° C. (240.8° F.); wash in keir only. (4) First chemick, of 0.35° chlorometric strength; temperature, 25° C. (77° F.); steep six hours; wash in roller washing machine. (5) Sour, hydrochloric and sulphuric acids mixed; wash in roller washing machine. (6) Second lye-boil, six hours, Mather's keir, with salt of soda lye at 2.2° Baumé; temperature, 110° C. (230° F.); wash in keir only. (7) Second chemick, of 0.25° chlorometric strength; steep six hours; wash in roller washing machine. (8) Sour, hydrochloric and sulphuric acids mixed; wash in roller washing machine. (9) Third chemick, of 0.15° chlorometric strength; temperature, 20° C. (68° F.); steep four hours; wash in roller washing machine. (10) Sour, hydrochloric, and sulphuric acids mixed; wash twice in roller washing machine. Finish.

*Madder Bleach.*¹—The *first* operation in A, B, C, D, and E is a wash after singeing. The *second* is, in A, lime-boil 430 lb. lime, ten hours; in B, 680 lb. lime, ten hours; in C, 500 lb. lime, ten hours, 35 lb. pressure; in D, 600 lb. lime with 10 lb. caustic soda, ten hours; in E, 500 lb. lime, twelve hours. The *third* operation in A, B, C, D, and E is wash. The *fourth* operation in A is lime sour, HCl, 2° Tw., one hour's steep; in B, HCl, 2° Tw.; C, HCl, 2° Tw.; D, $2\frac{1}{2}^{\circ}$ Tw.; in E, 2° Tw. The *fifth* process in B, C, D, and E is wash. The *sixth* operation in A is first soda ash treatment, 215 lb. soda ash, boil ten hours; in B 770 lb. soda ash, 214 lb. rosin, boil ten hours; in C (a) sweeten with 120 lb. soda ash, 1600 gallons water; (b) 450 lb. soda ash, 220 lb. rosin, caustic soda at 70° Tw. (= about 120

¹ See Note, p. 288.

solid $61\frac{1}{2}$ per cent NaHO), 14,000 gallons water, ten hours' boil, 35 lb. pressure; in D (a) 120 lb. solid, NaHO, boil three hours; (b) 500 lb. soda ash, 120 lb. solid caustic, 320 lb. rosin, 120 gallons water, ten hours' boil, water 16 in. above false bottom; (c) 120 lb. solid caustic, three hours' boil; E (a) 170 lb. soda ash, boil three hours; (b) 430 lb. soda ash, 190 lb. rosin, 95 lb. solid caustic, boil twelve hours; (c) 190 lb. soda ash, boil three hours. The *seventh* process in A, B, C, D, E is wash. The *eighth* process in A is chemick, 137 lb. bleaching powder in solution at $\frac{1}{2}^{\circ}$ Tw., ten hours' steep; in B at $\frac{3}{4}^{\circ}$ Tw., six hours' steep; in C, at $\frac{1}{4}^{\circ}$ Tw.; in D, at $\frac{1}{2}^{\circ}$ Tw.; in E, at $\frac{1}{4}^{\circ}$ Tw. The *ninth* operation in A, B, C, D, E is wash after chemick. The *tenth* operation in A is first white sour, H_2SO_4 , $2\frac{1}{4}^{\circ}$ Tw., one hour's steep; in B, white sour, HCl, 2° Tw., two hours' steep; in C, white sour, H_2SO_4 , at 2° Tw., pile one to three hours; in D same as C, in E same as C and D. The *eleventh* operation in B, C, D, and E is wash, squeeze, and dry, but in A three further operations were interpolated before this final washing, squeezing, and drying, viz. (a) second ash work, 130 lb. soda, ten hours' boil and wash; (b) second chemick, 70 lb. bleaching powder in solution at $\frac{1}{2}^{\circ}$ Tw., five hours' steep; (c) last white sour, H_2SO_4 , $2\frac{1}{2}^{\circ}$ Tw., one hour's steep.

Turkey Red Bleach.—With goods to be dyed turkey red a full madder bleach is not required as the dye is plain and no white design has to be preserved. The sequence of operations for 2 tons of cloth in a low pressure keir is as follows: (1) Wash (no singeing). (2) Boil in water for two hours; wash. (3) Lye-boil: A, 20 gallons caustic soda at 70° Tw., specific gravity 1.350. Boil ten hours; wash. B, 15 gallons caustic soda at 70° Tw., specific gravity 1.350; boil ten hours and wash. (4) Sour sulphuric acid at 2° Tw., specific gravity 1.010. The pieces are laid in stone cisterns and the liquor pumped over them till submerged. Steep two hours. (5) Wash and dry.

Bleaching Cotton with Hydrogen Peroxide.—Cotton, it is needless to say, is usually bleached with chloride of lime, which is much cheaper. However, hydrogen peroxide is occasionally

used for bleaching certain classes of cotton goods, such as fine counts of yarn. A perfect, full bleach is got by combined treatment with hydrogen peroxide and bleaching soda. The goods are first treated with a solution of carbonate of soda, then with dilute caustic soda, 10 parts of caustic soda, specific gravity 1.16, to 100 parts of water in a bowking keir for about six to eight hours in the usual manner and afterwards rinsed and squeezed. After this preparatory treatment the goods are put through a souring bath, specific gravity 1.03, steeped in a solution of mixed caustic and carbonated alkali, and piled for one hour. After a good washing the goods are passed through caustic soda, specific gravity 1.07, washed again and put through a wringer. They are next entered in the hydrogen peroxide bath which has been prepared by diluting $2\frac{1}{2}$ gallons of commercial peroxide with eight times that quantity of water, 8 oz. of 20° Baumé ammonia being added. In this liquor the goods are left for at least eight hours until perfectly white at a temperature of 25° to 30° C. (77° to 86° F.), and are afterwards put through a centrifugal machine dried in the air (exposed to the light). According to Friedhomme and Koechlin an addition of magnesia instead of ammonia to the bleaching bath is very favourable, because in such case heat may be applied owing to the formation of magnesium peroxide which is difficult to decompose. The material to be bleached is either left in the liquid for about ten hours or is merely impregnated therewith, the excess being wrung out and the stuff exposed to the air as when ammonia is used.

Saget's Process of Bleaching Cotton by Sodium Sulphite or Bisulphite and Turkey Red Oil.—The sulphite is stirred into milk of lime, slaked lime being mixed with its own weight of turkey red oil, and the requisite amount of water sodium of 30° Baumé equal in weight to the lime being then added. The resulting liquid has a milky appearance. The goods are padded with this liquid at about 120° to 140° F., then steamed for one and a half to two hours, washed in hot water, soured in lukewarm dilute acid for an hour out of contact with air slightly chemicked, rewashed and dried. The bleaching action does not take place

immediately but only after souring) and when the goods have been left in a heap for two to three hours. If they are washed at this stage and lightly chemicked a good white is obtained.

The Thies-Herzig Full Bleach Process for Cottons. (1) *Preliminary Treatment—Sour Steep.*—The goods are steeped in a special sour, 10 grammes of 60 per cent sulphuric acid, or 16 grammes of 30 per cent hydrochloric acid, and 9.5 grammes of 75 per cent hydrofluoric acid per litre. This sour is to remove mineral and organic impurities whilst the hydrofluoric acid removes silica. Duration of steep, four hours in its own weight of sour. Steam in a steamer for half a minute, wash. If the goods be clean this preliminary treatment may be omitted. (2) *Steep in a Weak Alkaline Lye.*—The cotton is first steeped all night in a weak alkaline lye, $\frac{1}{2}$ per cent caustic soda lye at 122° Tw. If the stuff is very unclean this operation is repeated. (3) *Washing.*—The next process is washing in water containing .0005 per cent of magnesium chloride, 5 lb. per 1000 gallons (50 grammes of 25 per cent magnesium chloride per litre). This magnesian water deposits sparingly soluble magnesia on the fibre which exerts a beneficial action in so far that fabrics so impregnated with magnesia or other alkaline earths are neither mercerized nor tendered by subsequent boiling with strong caustic soda. The pieces are then squeezed so as to leave in the material about its own weight of water. (4) *Steaming in a Special Keir.*—The material is now transferred to the bowking keir and subjected to steam at 212° F. for two or three hours, and the function of this steaming is a preparatory one to the succeeding lye-boiling in strong caustic soda lye. This lye being introduced in a hot state the mercerization of the goods is prevented, the steam expelling the air which would enable the strong alkali to corrode the fibre. It is claimed that the conjoint action of the alkaline earth and heat results in the formation of reducing bodies which are readily removed in the subsequent lye-boiling and besides counteract the oxidizing action of the latter. (5) *Lye-boiling with Strong Soda in the Special Keir.*—After the steaming in the keir a boiling solution of strong caustic soda

containing a little rosin ~~is~~ run in. This solution is prepared from 1 cwt. of 58 per cent soda ash causticized with lime and diluted to 110 to 120 gallons, 20 lb. of rosin being boiled therein. This gives a lye of about 5 to 7 per cent strength. As 30 cwt. of cotton occupies about 140 cubic feet this quantity of lye only suffices to impregnate the material thoroughly. The use of strong lyes was formerly uneconomical as the goods require two to three times their own weight of lye to cover them. The circulation of the lye and steam is kept up by a pump which draws and delivers them into a vessel, thence into a heated vessel, from which they return to the keir where the fabrics are stowed. The vessel contains a perforated pipe through which a part of the steam escapes into the open air, thus compensating for the dilution produced by the saponification process within the vessel and maintaining the uniform strength of the lye. After treatment with this solution for about three hours the material is washed with boiling water, followed by bleaching with sodium hypochlorite or bleaching powder and then souring, the material being finally washed. These operations are performed as usual, the only difference being that the liquors are merely one-third the ordinary strength. The chief advantages of this process as contrasted with the ordinary process, lime and rosin soap, are rapidly absolute bleaching and unimpaired strength. Indigo blue can be more readily discharged than usual when goods have been bleached by this method.

Note to comparison of the different operations of madder bleaching (p. 284) and their sequences at different epochs in the history of madder bleaching.

- A in use in 1845, Thomson's 12,000 lb. fabrics low pressure keir.
- B " " 1850, Thomson's 12,000 lb. cloth low pressure keir.
- C " " 1879, Crum's 12,000 lb. cloth Barlow's keirs.
- D " " 1879, Crum's 12,000 lb. cloth low pressure keir.
- E " " 1879, Crum's 12,000 lb. cloth low pressure keir.

CHAPTER XX.

BLEACHING OF HEMP AND JUTE.

Bleaching Aloe Fibre, Sisal Hemp, Century Plant, White Rope Fibre, Vegetable Silk (Pita Fibre).—These are different names for practically the same material, the source of which is the Agave, a species of plant indigenous to tropical South America, Mexico, and the Southern States of North America. Sisal hemp can be bleached in accordance with its practical application by an alkaline hydrogen peroxide liquor, 1 to 4, the operation being repeated when the sisal hemp is required as web for upholstery purposes.

Bleaching Manilla Hemp (Musa textilis) by Sodium Bisulphite.—The fibres are first scoured by gentle boiling in a carbonate of soda lye (4 per cent) for three hours, or a caustic soda lye of equivalent strength for a shorter period, two to three hours. Using the caustic alkali the hemp parts with some of its colouring principles during the boiling, the liquid turning pale yellow. The scoured hemp is then entered in a bleaching bath of sodium bisulphite solution, where it remains for about twelve hours. The fibres which are now quite white except at the points of attachment are carefully washed, and when dried exhibit their original lustre and strength.

Manilla Hemp (Musa textilis), Bleaching of.—Manilla hemp is bleached by hydrogen peroxide in the same way as jute. The commercial hydrogen peroxide, 3.2 per cent, is diluted with only five to six times its volume of water. The liquid is then rendered alkaline with about 2 per cent of ammonia. The Manilla hemp steeped in this bath one to two days, if not then sufficiently bleached is re-subjected to the same process. The goods are then withdrawn, squeezed, and

steeped for a short time in a dilute solution of sodium bisulphites, followed by suitable washing and drying. The lustre and strength of the fibre are retained. The various kinds of hemp behave somewhat differently under the action of hydrogen peroxide. Before bleaching they must be scoured by a weak alkaline lye, and the bleaching liquor may be prepared by diluting hydrogen peroxide solution with 4 volumes of water, ammonia being added to alkaline reaction. In the case of Russian or Prussian hemp (*Cannabis sativa*) the material is steeped in the bleaching liquor for three to four days, whereas Italian hemp will be sufficiently bleached in about one and a half days. After being withdrawn from the steep the material is slightly washed, squeezed, and hung up to dry while still damp, preferably in the air.

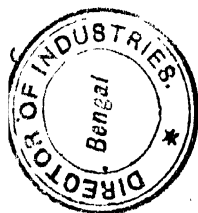
Bleaching Jute with Hydrogen Peroxide.—Jute must always be boiled before bleaching with a 5 per cent solution of soda ash and washed after the lye-boil. Jute (Chinese and East Indian fibre or fabrics) is bleached with a 10 to 12 per cent (vol.) solution of hydrogen peroxide containing 2 per cent ammonia 20° Baumé. The jute is steeped in this bath for one or two days at 77° to 86° F., when they are taken out and air dried. The cleaned material may also be dipped in the above bleaching liquor and properly steeped, the surplus liquor being then expressed in a squeezing machine and the still damp material dried slowly at 68° F. This latter operation must be repeated if a successful result is desired. With commercial hydrogen peroxide diluted with eight times its bulk of water and rendered slightly alkaline with ammonia the jute will not be sufficiently bleached even by a steep of two days' duration, and it is only by repeating the treatment for the same period and supplementing it with an after treatment with sodium bisulphite that a nearly pure white can be obtained. Jute, especially fine yarn, can be bleached by the permanganate process. After treatment with carbonate soda and permanganate solution the goods are worked about in dilute hydrochloric acid containing hydrogen peroxide solution and then washed. The process must, however, be repeated in order to obtain a perfect white.

In a recent process patented by Martin the juice is first of all boiled in an autoclave for four hours in a solution containing for 12 cwt. of material, 1 cwt. soda-ash, 6 lb. each of turps and carbon disulphide. Here an effort is made to reduce the consumption of bleach to one half.

The Permanganate Process of Bleaching Jute.—In a more recent process jute yarn is first treated with a solution of carbonate of soda at 149° F., and after draining is steeped in a 5 per cent solution of potassium permanganate. After half an hour the goods are withdrawn, and worked in dilute hydrochloric acid containing a little bisulphite of sodium or hydrogen peroxide followed by washing in clean water. To bleach the goods still further the process should be repeated. The jute loses 3 to 4 per cent in weight.

The permanganate process produces a first-class white which will not alter on exposure to the air when the suitably scoured jute (or other fibres) are treated for some time, three to four hours, in a solution of sodium hypochlorite (2° B.) before steeping in the permanganate. After squeezing and washing the goods are soured in a weak acid, preferably acetic acid.

After squeezing the jute is steeped for an hour in a $\frac{1}{2}$ per cent solution of permanganate. The material now stained brown is steeped in sodium bisulphite 950 of water, 50 of bisulphite of 38° Baumé, and is left there for about three-quarters of an hour. The bleached material is thoroughly rinsed, then steeped in a soap bath consisting of a $\frac{1}{2}$ per cent solution of soap with a little ultramarine blue or methyl violet to improve the white. The jute is treated in this bath fifteen to twenty minutes. Its lustre is improved.



CHAPTER XXI.

BLEACHING OF LINEN AND COTTON YARNS.

WEIGHT OF YARN.—*Numbers of Linen Yarns—Moistened and Dry Yarns—Different Kinds of White—Loss in Weight.*
 —LYE-BOILING.—CHEMICKING.—*Chemicking of Cotton Yarn—Chemicking of Linen Yarn—Chemicking on Reels—Chemicking on Frames.*—WASHING.—SQUEEZING AND DRYING.—BLEACHING OF COTTON YARN.—CREAMING BY MALACRIDA'S PROCESS.

Bleaching of Linen Yarn.—The methods about to be described are specially suitable for linen and hemp yarn. They are also applicable to cotton yarns, but, as these are easier bleached, weaker lyes and chemicks are used and it is not necessary to make the same arrangements for the penetration of the chemicals.

Numbers of Linen Yarns.—The packets of yarn have a constant length of 33,000 metres, 110,000 feet; it follows, therefore, that the stouter the yarn the heavier is the weight of the packet. The weight of the packet multiplied by the number equals a constant of 540. Example: a No. 6 packet of yarn weighs $\frac{540}{6} = 90$ kilogrammes (say 198 lb.); a No. 50 packet weighs $\frac{540}{50} = 10.8$ kilogrammes (say 24.7 lb.).

The following table gives the weight of the numbers of the yarns most frequently spun. The weight of the packet is given in kilogrammes and half kilogrammes:—

TABLE SHOWING WEIGHT OF PACKET IN KILOGRAMMES¹ OF DIFFERENT NUMBERS OF LINEN YARN.

Number of Yarn.	Weight of Packet.	Number of Yarn.	Weight of Packet.
6	90	32	17
8	68	35	16
10	54	38	14.5
10½	50	40	14
14	40	45	12
15	36	50	11
16	34	55	10
18	30	60	9
20	28	65	8.5
22	25	70	8
23	24	75	7.5
26	22	80	7
28	20	90	6
30	18	100	5.5

When the weight of a packet of linen yarn is too heavy it is made into parcels of half packets or quarter packets. The packet of yarn is divided into 100 skeins (hanks).

Moistened Linen Yarn and Dry Linen Yarn.—Yarns which are spun before receiving the final torsion pass through a trough containing hot water, where they are de-gummed. These yarns are termed moistened yarn, in contradistinction to those which do not undergo this process and are therefore termed dry yarns.

Different Classes of White.—Those linen yarns which have received one or more lye-boils are termed boiled yarn. They retain their grey colour, but it is brighter. Those linen yarns which have been both lye-boiled and chemicked, or simply chemicked, are known as cream yarns. They are of a more or less bright yellow colour. It is but seldom that yarns are completely bleached before being woven. Linen yarn bleachers make different kinds of white—quarter white, half white, three-quarters white, white, flower white.

Loss in Weight.—The number of the yarn being dependent on the weight of the packet, and the price of the packet

¹ To convert into lb. multiply by 2.2.

increasing with the size of the number, it follows that it is quite to the interest of the yarn merchant that the yarn should lose but as little as possible in bleaching. On the other hand, no one can expect to bleach yarn without its losing a certain proportion of its weight, because the chemicals used in bleaching render the colouring principles and other impurities soluble in water and thus facilitate their expulsion. Yarns bleached under favourable conditions lose between 10 to 20 per cent of their weight according to the degree of whiteness to which they have been brought in the process. Lye-boiling greatly decreases the weight of yarn. Chemicks, whilst furthering the bleaching process more in the beginning, do not cause so much loss in weight. It must not be lost sight of that it is very difficult to bleach fabrics which have been too energetically chemicked. They are unable to support the vigorous lye-boiling essential to a fine white. The yarn of which the large numbers consist and which is not intended for fine white is "creamed". If they were woven in the state of raw or crude yarn or simply boiled, they would be very difficult to bleach, because the chemicals would not penetrate into the interior of the yarn. Fine fabrics intended to be bleached to a pure white ought to be manufactured from yarn which has been well lye-boiled, but not chemicked. In this way they are able to stand, before being chemicked, the energetic lye-boils indispensable to obtain a fine white.

Lye-boiling of Linen Yarn.—Sometimes this operation is confined to steeping the yarn in hot water to dissolve gummy substances. The water ought to have at least a temperature of 50° to 60° C., and the yarn must be left there about twelve hours; this water is then run off, and the yarn washed by running cold water on to it. The keirs used for boiling (*débouillir*) the yarn are analogous to those described for lye-boiling. Wide keirs are to be preferred so as to facilitate the stowing of the hanks. It is advantageous to provide the keirs with lids, so as to allow of boiling under pressure, or at any rate to prevent loss of heat. Circulation of the lye is effected by injectors or centrifugal pumps. The illustration (Fig. 38)

shows a keir made by Fontaine of Lille. The lid is raised by a winch which hangs it below a wagon running on rails fixed to the ceiling. The lid is removed whilst the keir is being charged and is brought back so as to close the keir during boiling. Circulation is effected by an injector which could

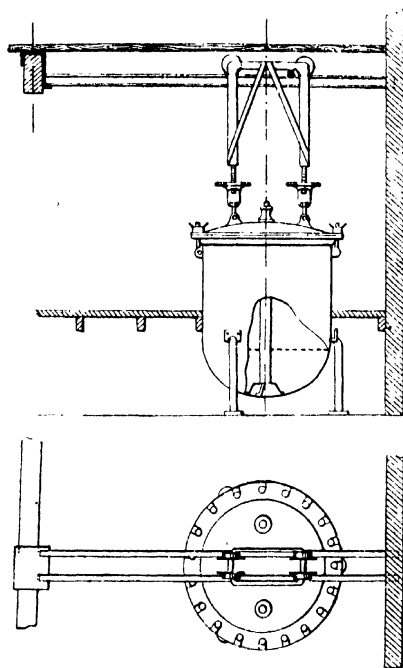


FIG. 38.—Keir for boiling yarn.

easily be replaced by a pump. The yarns are boiled with carbonate of soda, or with carbonate of soda containing 20 per cent of caustic soda, or with caustic soda alone. It is difficult to indicate in a general manner the composition of the lyes, that depends upon the end or object which the bleacher has in view. If he wants a fine white he ought to lye-boil strongly; if he desires to preserve the weight he ought to use

weak lyes—generally a lye of carbonate of soda with 20 per cent caustic of 1.5° to 2° Baumé is the strength used. Boiling is kept up for six to eight hours. The yarns must be packed in the keir so that they are uniformly lye-boiled. The following is a good method of working. The lye is prepared in a special tank, then the lukewarm lye is run into the keir,

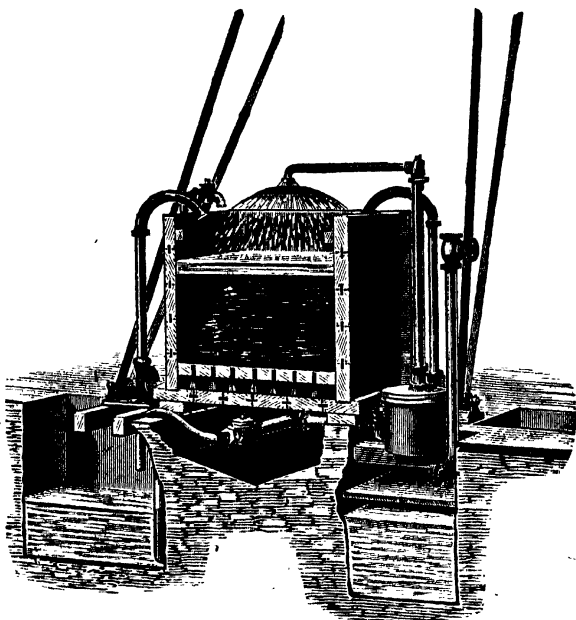


FIG. 39.—Mather & Platt's yarn-bleaching keir.

and as fast as it is being run in the hanks are laid into it in such a manner that they are well impregnated with lye and not too tightly packed. All the hanks being stowed, they are weighted down so as to prevent them from rising out of the liquid. Lye is run in until all the yarn is well covered, the lid is put on, and the temperature gradually brought to 100° C., or higher. The yarns may also be packed in the keir in

the dry state, weighted down, and the lye run on; then, when the yarns are well impregnated, the lye is circulated and the temperature gradually brought to the boil. When the boiling is over the lye is run off and then the yarns are washed. If possible, the washing is commenced with hot water, which carries off better the substances rendered soluble by the lye, and the washing is then continued with cold water. In any case it is not good practice to bring the fabrics suddenly from a high temperature to a low temperature, or vice versa, e.g. steeping cold yarn in hot water, or taking them out of that to place them in cold water. By attending to this observation many annoyances produced by no apparent cause may be obviated.

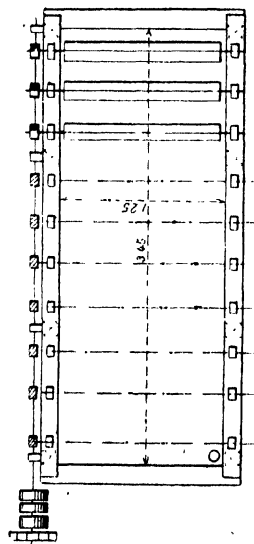
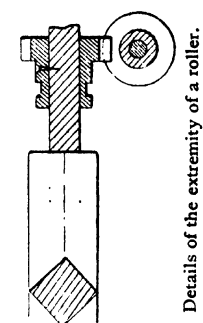
Fig. 39 shows Mather & Platt's yarn-bleaching keir, which is designed to bleach cotton yarn, either in hanks or in the warp forms, without removing it from the vessel into which it is first placed. The process is as follows: The hot alkali solution is circulated by means of a distributing pipe through the action of an injector or centrifugal pump to scour the yarn; then water is circulated by means of a centrifugal pump for washing. The chemick and sour liquors are circulated also by means of pumps, so that without the slightest disturbance to the yarn it is quickly and economically bleached.

Chemicking of Cotton Yarns.—Many plans have been proposed for chemicking yarns. They all have the same end in view, viz. the thorough penetration of the liquid throughout the whole of the hanks of yarn. As they are easily penetrated they may be piled in a tank, pressed down, and the chemick run on to the top of them. Circulation being maintained by the pump, the chemick is brought thoroughly in contact with all the parts of the hanks. Instead of packing the hanks in the dry state, it is better to run in the chemick as they are being packed in the cistern. They are not squeezed together so much, and a more uniform white is got.

Chemicking Linen Yarn.—The above method is not suitable for linen yarn, hemp or jute, as the chemick does not

penetrate equally throughout every portion of the hanks. Some portions are bleached white, others remain grey.

Chemicking on Reels.—By the plant the dimensions of which are shown in Fig. 40, 100 kilogrammes of linen yarn may be creamed at a time. The chemick is contained in a beck built of masonry and lined with cement, 3.45 metres in length, 1.25 metres in width and 0.50 metre in depth (say 11.3 feet \times 4 feet \times 1 foot 8 inches). It is filled with chemick to the depth of 0.25 to 0.30 metre (say 10 to 12 inches). The walls of the beck are surmounted by a wooden framework. This framework supports the reels which carry the hanks of yarn and the shafting which imparts a rotatory motion to them. The hanks of yarn are hung on square wooden arms or reels 0.10 to 0.12 metre square (4 to 4 $\frac{1}{2}$ inches). The ends of the reels are prolonged by turned iron arms of 0.05 metre (2 inches) diameter. A toothed wheel is fixed to the end of each of these arms. When the reels are charged with yarn they are brought to the chemicking cistern and rest on bearing blocks on each side of the framework. The reels are placed parallel to one another at a distance of 0.33 metre (13 inches) from axis to axis. A driving shaft of 0.035 metre (1 $\frac{3}{8}$ inch) diameter, fixed on the side of the framework, carries a series of endless screws which gear into the toothed wheels fixed to the end of the bearing shafts of the reels, and impart to them a slow movement of rotation (five to six turns a minute). The screw shaft is propelled by a belt and pulley. There are three pulleys, one fixed and two free. On one of the two pulleys there is a straight belt, on the other a cross belt. By a suitable gearing arrangement either the straight or the cross belt may be made to bear on the fixed pulley. In this way the motion of the reels may be reversed. Sometimes this is done automatically by an arrangement of levers and counterpoises. It must be observed that the reels are not fixed into the framework of the chemicking cistern. The hanks are first hung on to them, then two men seize them, each by one end, and bring them into position on the chemicking cistern, and, when the whole are in position, the driving shaft, carry-



Plan.

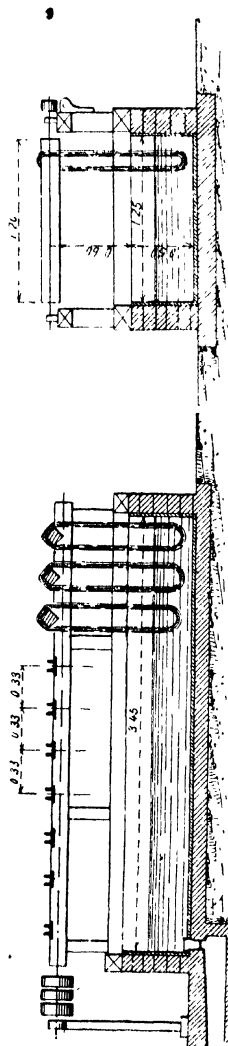


FIG. 40.—Chemicking of linen yarn.

ing the bevel wheels which impart the movement of rotation, is started. Each portion of the hanks is successively exposed to the action of the chemicking liquor and to the air, thus realizing the best conditions for the chemick to produce the most energetic effect. The drawback is that the yarn gets scraped and deadened on the rollers; it must not, therefore, be reeled for too long a time. An hour to an hour and a

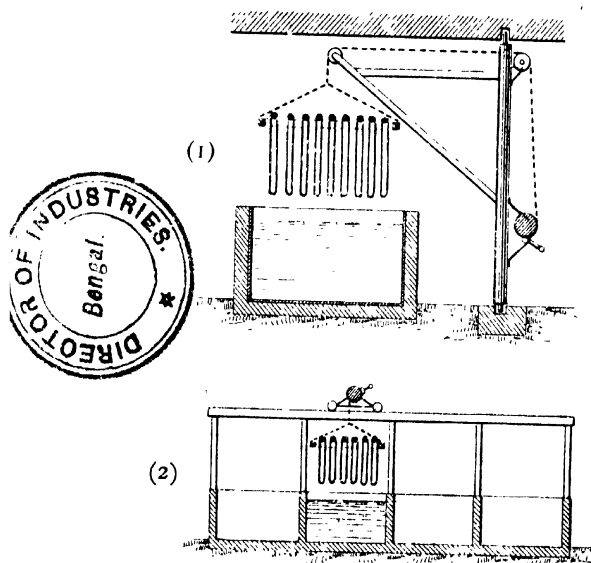


FIG. 41.—Chemicking on frames.

half at the maximum is sufficient for one operation. If the yarn bleaches too quickly the chemick will only have a superficial action, for it will not have time to produce a proper effect on the interior fibres of the yarn. If the yarn bleaches too slowly it is scraped in contact with the reels and becomes frayed. The following are the strengths of the chemicks employed successfully by Tãilfer, using chloride of lime in the cold :—

		Chlorometric Strength in Degrees.
For yarns from No. 10 to No. 20	- -	3
" " 20 to No. 35	- -	2
" " 35 to No. 45	- -	1.5
" " 45 upwards	- -	1

Chemicking on Frames (see Fig. 41 (1)).—The chemick is contained in a cistern of masonry, or in a wooden vat. The hanks are hung on parallel wooden bars, the ends of which are fixed into a wooden frame. This frame is hung by a chain which, after passing over two pulleys, is rolled on a windlass. The whole is worked by a movable crane, by means of which the hanks of yarn may be conveyed from one cistern to another. All the hanks being suspended on the frame are brought above the chemicking cisterns by turning the crane, and by means of the windlass are plunged into the liquor. To ensure better contact of the liquid with all the portions of the hanks, a movement of oscillation is given to the whole from above downwards. The hanks may also be taken out of the chemick, exposed some time to the air, and replunged afterwards in the liquor. When the yarn has been steeped the necessary time it is drawn up by the windlass and, turning the crane, it is brought into another cistern containing clean water. When it has been sufficiently washed there, it is again brought by the crane into the scouring cistern, and from there into the washing cistern. Several successive chemicks with intervening sours may thus be given with but little labour. This method of washing by simple steeping is sufficient between the chemick and the sour, but it would not be sufficient for the washing preceding drying, which requires to be done more energetically. This system is well adapted for fine yarn because it does not fray the yarn as in reeling. It also answers very well for cotton. Instead of arranging the cisterns in a circle around the crane they can be placed in a straight line (see Fig. 41 (2)). The windlass for manipulating the frame is placed on a bogie the wheels of which run on two small beams of quartering. By moving the bogie the hanks are shifted from one cistern to another.

Washing.—The hanks are washed by hand in water, taking them out and plunging them in eight or ten times. The machine, the general arrangement of which is illustrated in Fig. 42, is very simple and gives good results. The hanks of

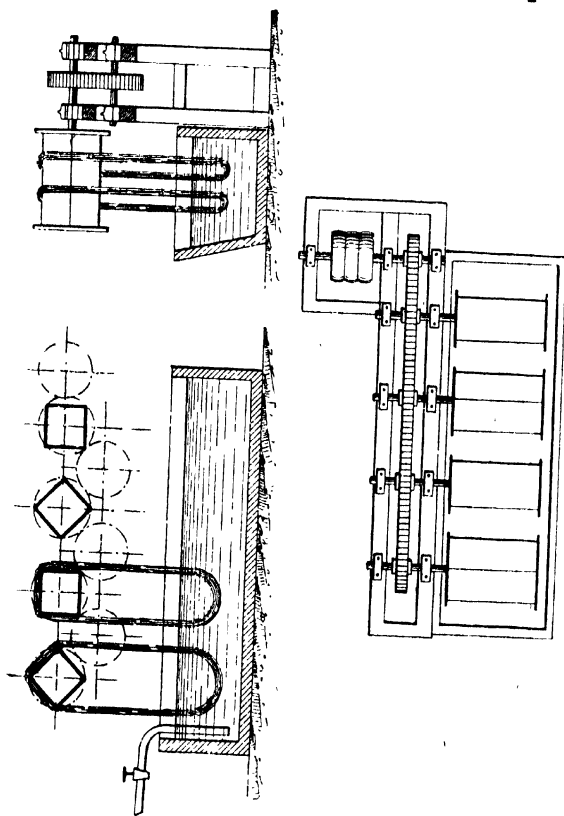


FIG. 42.—Machine for washing hanks of yarn.

yarn are hung on square wooden reels 0·20 metre to 0·25 metre, 10 inches, square. The hanks dip to half their height into a cistern the water of which is being continually renewed. Each machine comprises four or five reels which drive one another by gearing with an arrangement for automatically

reversing the rotatory movement periodically. In this way the yarn moves round alternately first in one direction and then in the other. The reels on which the hanks are hung have one extremity free; the hanks are placed thereon and removed without stopping. The workman whose duty it is

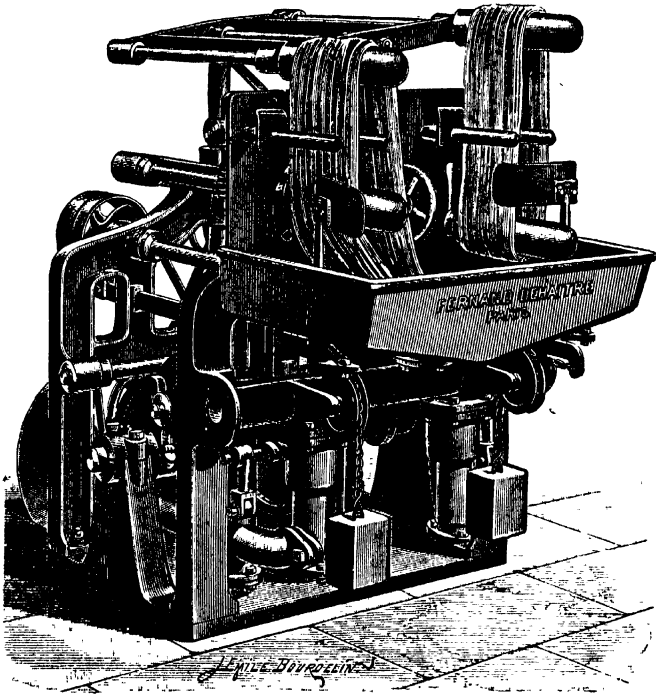


FIG. 43 —Sulzer's machine for washing hanks of yarn.

strips one reel, hangs on a fresh lot of hanks, passes on to the next, and so on.

Sulzer System, Machine for Washing Hanks of Yarn.—This machine is equally suitable for washing hanks of cotton, wool, silk or linen. The machine comprises a series of guindres on which the hanks are placed. These guindres may be raised

upwards according to the length of the hanks. Two perforated injection pipes distribute the water which penetrates into the hank. In the lower part a squeezing roll lined with rubber presses on the guindre with which it is driven by gearing. The hank is thus squeezed at its lowest point between two rolls, the water runs away immediately without again coming into contact with the hank which continually receives clean water from the injection pipes. Underneath the hanks is a cast-iron tank with a discharge pipe for the dirty water. To secure uniform washing the machine is fitted with automatic guides which keep the hank in the right position on the rolls. All the parts of the machine in contact with the hanks are of bronze. The injection tubes can be easily removed and cleaned. When the pressure from the water main is less than 10 feet, a centrifugal pump must be installed to increase the pressure. The hanks once washed are squeezed, and retain very little water when removed from the machine. All the movements of the machine being automatic, a single workman can attend to two machines, having only to remove and replace the hanks. The machine as shown in the engraving consists of only two elements, but several machines may be coupled together to form a machine of twelve elements and even more. With two elements 1·8 metric tons of cotton hanks may be washed in ten hours, and the machine with its driving gear only occupies the space of 1·6 metres by 1·6 metres.

Gantert's Machine for washing hanks of yarn consists of a round or oval trough combined with a series of 8 to 12 radial horizontal arms above the trough. A roller is carried on the outer end of each arm which acts as its axis and the different rollers revolve above the trough. The hanks are hung upon the rollers and their lower ends dip into the water in the trough in which a partition is fitted. The water enters on one side of this partition where the washed hanks are taken off, circulates round the trough and escapes on the other side of it where the hanks to be washed are entered. By a somewhat complicated arrangement the hanks are moved along whilst the rollers revolve and cause the hanks to vary their position

in the water. The arms, rollers and hanks have besides a backward and forward motion. The machine may be constructed

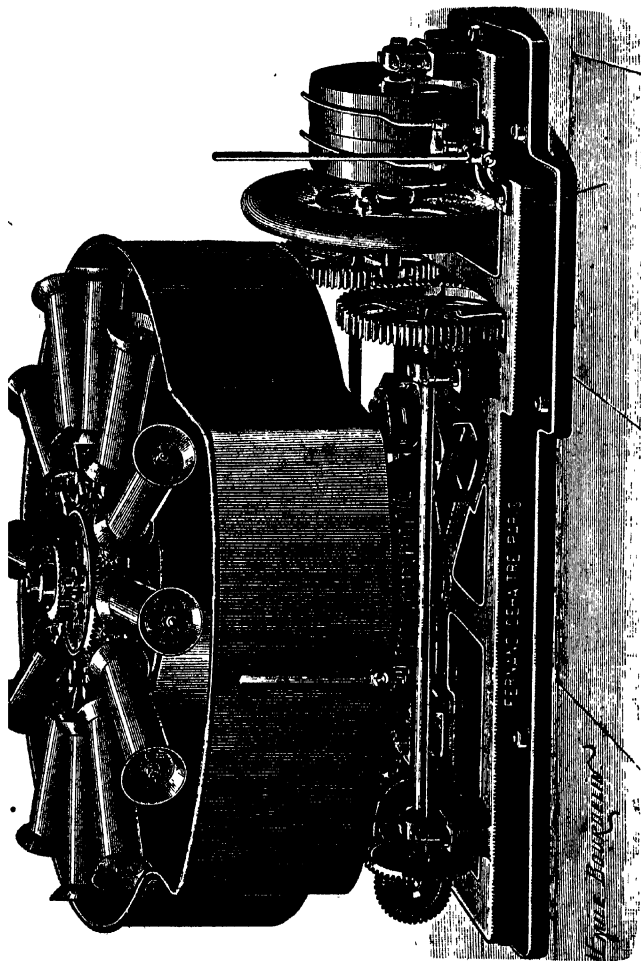


FIG. 44.—Gantert's washing machine for hanks of yarn.

of such a size that one circulation will give a sufficient washing. The hanks to be washed are constantly put on the rollers by

an operator on one side of the water trough division and removed thoroughly washed on the other side of the division. The whole action imitates fairly well the hand washing of a hank of yarn.

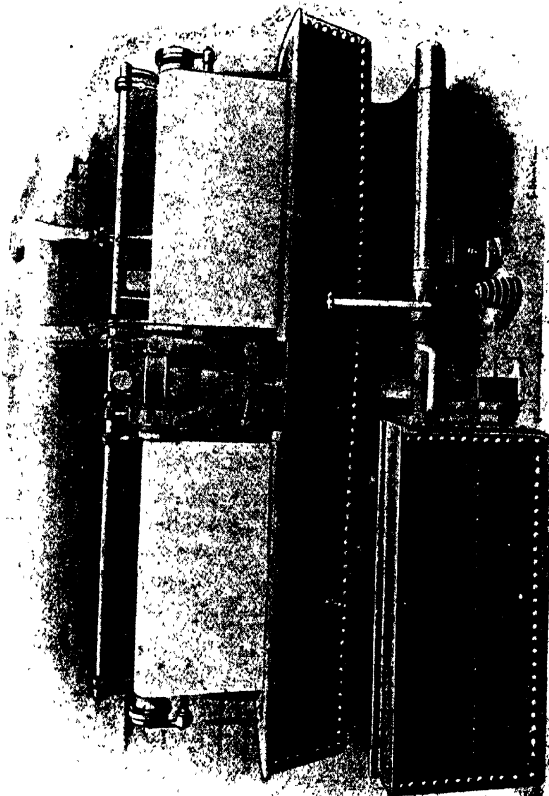


FIG. 45.—Mercerizing machine.

*Machine for Mercerizing Cotton Yarn (La Parisienne).—*La Parisienne was specially constructed to meet the important requirements of the sewing cotton industry (L.V. Brand).

in which it has been at work for several years. The machine comprises two pairs of guindres fixed symmetrically and balancing each other reciprocally; lined with ebonite there is no danger of rust. The lower guindres approach the upper ones during charging and discharging. The tension is imparted by means of a screw worm; it can be regulated at will. A reservoir placed under the machine contains the soda solution, kept at a constant strength by circulation over lump soda. Whilst the workman is charging his machine a small centrifugal pump delivers the soda solution in the tank. Once the machine is charged and the tension given by the screw, the workman puts the machine into gear, and the operation proceeds automatically, whilst the workman is employed in charging and discharging another machine. Impregnation is effected by steeping; it is complete, rapid and uniform. The duration is regulated by the variation of the cams. The machine stops itself automatically to allow drainage to occur, and the valve opens of its own accord to allow the soda to return to the reservoir, then it closes. The machine then starts again, and at the same time the injectors of water under pressure open, which produces an energetic washing. The first wash waters strongly charged with soda are collected to form new solutions or for use in bleaching or dyeing operations. Then automatically the overflow pipe changes its place to run the final wash waters which contain but little soda down the drain. By this ingenious arrangement the greater part of the soda may be recovered. The machine stops automatically at the end of the washing period, and the workman has only to charge it and recharge it. The completely automatic working of the machine enables three machines to be wrought with a single workman helped by a boy, producing about 880 lb. of cotton per day. No false manœuvre is to be feared; there is never any mishap. The driving parts of the guindres are mounted on roller bearings imparting a very gentle rolling motion. The horse-power is insignificant, it may be taken as $\frac{1}{4}$ horse-power. The space occupied is 2 square metres. There is no projection of soda, and thus there is no danger.

Tierce of Rouen makes a machine the reels of which are arranged on a radial manner to a central shaft and free at the other extremities, and each of these reels revolves with three simultaneous movements. They turn on their own axes, are carried forward by the rotatory motion of the shaft to which they are attached, and finally an oscillatory motion from above downwards is imparted to them which dips the hanks in the water. This machine intended for the washing of ribbons answers very well for washing hanks of yarn.

Squeezing and Drying: Air Drying.—After being washed the yarn is squeezed (Fig. 14) to expel a portion of the water which it retains. This squeezing may be done by wringing or by passing the yarn through two compressing rollers or by a centrifugal machine (Figs. 10-13). Air drying is the best method. The hanks are hung on wooden rods and exposed in hot or cold air drying machines. After six to eight hours, linen or hemp yarn should be handled whilst still wet. A workman passes a stick through the interior of the hank and gives it several cuts which separates the threads which have become glued to one another and render them flexible. The yarn is then allowed to dry completely. The dried yarn, so as to render it still more flexible, is sometimes passed through rollers which carry the yarn forward on their rotatory motion.

Bleaching of Cotton Yarn.—To obtain a very fine white.

- (1) Boil eight hours with sal soda, 2° Baumé; wash. (2) chemick, 0·75° chlorometric strength; steep four hours; wash. (3) Sour sulphuric acid, 0·5° Baumé; wash. (4) Lye-boil, eight hours, salt of soda; wash. (5) Chemick as before. (6) Sour as before. Be very careful with the last washing before the blue or before drying. If not white enough give two lye-boils before the first chemick.

Creaning by Malacrida's Process.—Malacrida of Milan has patented a process for the manufacture of a lye which possesses special properties. Instead of boiling the yarn with full steam for a greater or less length of time it is plunged in the cold in this concentrated lye of 2° Baumé for about two hours. It is

then washed and chemicked in the usual way. The advantages of the process are : (1) Economy of coal, since there is no need for steam. (2) The yarn suffers no loss in weight. This last point is very important to yarn merchants, for the number of the yarn depends on the weight of the packet. This lye is prepared in the bleach works where it is used, and its price is no higher than soda ash. This lye has been successfully used for about six years in Ireland, Belgium, and Italy.

CHAPTER XXII.

DRYING.

Drying by Steam—Drying by Hot Air—Drying by Air.

AFTER the fabrics are bleached white they receive a final washing. This washing should be done with special care, and in a water specially adapted for the purpose, so as to free the fabrics from all trace of the chemicals used in bleaching. This operation is one of the most important, for any traces of soda, chlorine, or acids remaining in the fabrics would, in the drying, act very injuriously. It is rare that fabrics are dried before being blued and finished. It forms no part of the plan of this work to treat upon finishing, but a few words may be said in regard to drying, because it has an influence on the quality of the white and its preservation. Drying may be effected by (1) steam, (2) hot air, or (3) air at the ordinary temperature of the atmosphere.

1. *Drying by Steam.*—The fabrics are dried over a series of copper rollers, the interior of which is heated by steam. This mode of drying, which is the most rapid, answers very well for cotton fabrics. It does not suit so well for linen or hemp. It renders them harsh to the touch, and does not allow the grain to appear; they assume a glazed, cotton-like appearance, which must be avoided. If this method be used to save time with linen or hemp fabrics, they must not be completely dried by the machine, but finished in a free air drying machine. When the fabrics are not very white the drying on the cylinders turns them yellowish, and if they have been blued, the union of the yellow and the blue gives them a greenish cast. The fabrics are kept extended during drying on tenter

frames, the fabrics being seized hold of by the selvage and kept in position by pegs and cords. The pieces pass above the rolls, but do not come in contact with them.

Horizontal Drying Machine.—This machine (Fig. 47) is used for drying cloth after bleaching, dyeing, or starching. The framing is machined both on the upper and lower faces, as are

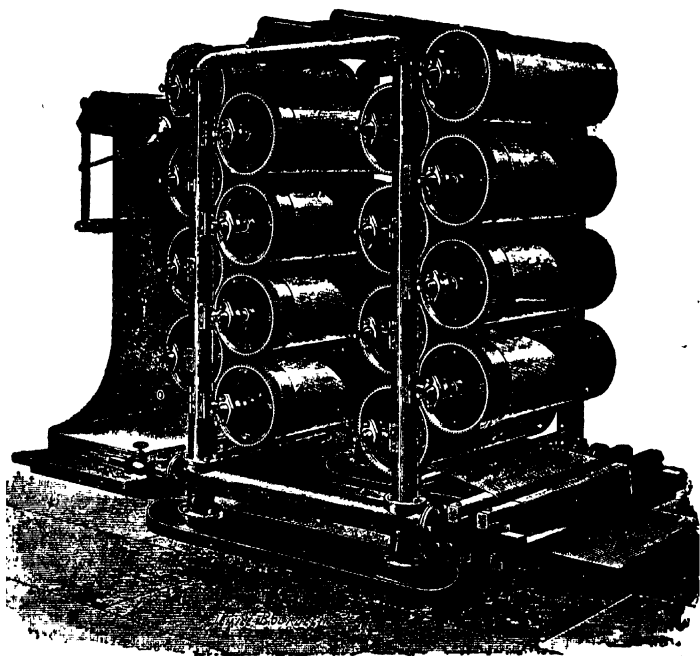


FIG. 46.—Vertical drying rolls (Fernand Dehaitre, Paris).

also the cylinder stands and fixing throughout. The cylinders are of copper or of tinned iron; steam is supplied to them through the tubular framing on one side of the machine, and a simple and efficient steam separator is provided to ensure the dryness of the steam. The condensed water is completely removed from the interior of the cylinders by means of specially large buckets, and passes away through the tubular framing on

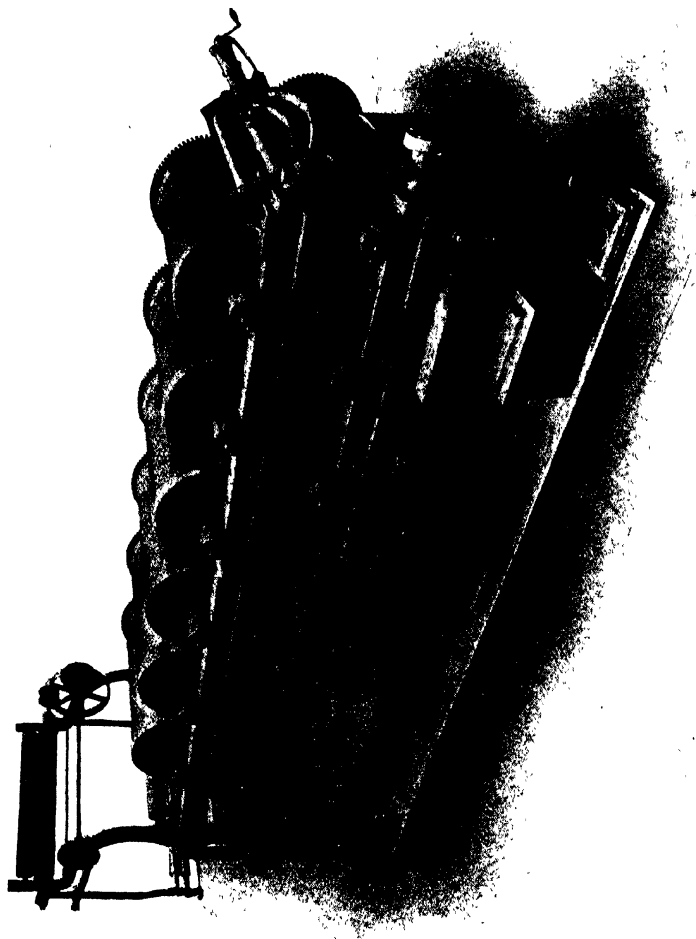


FIG. 47.—Drying rolls (Mather & Platt, Manchester).

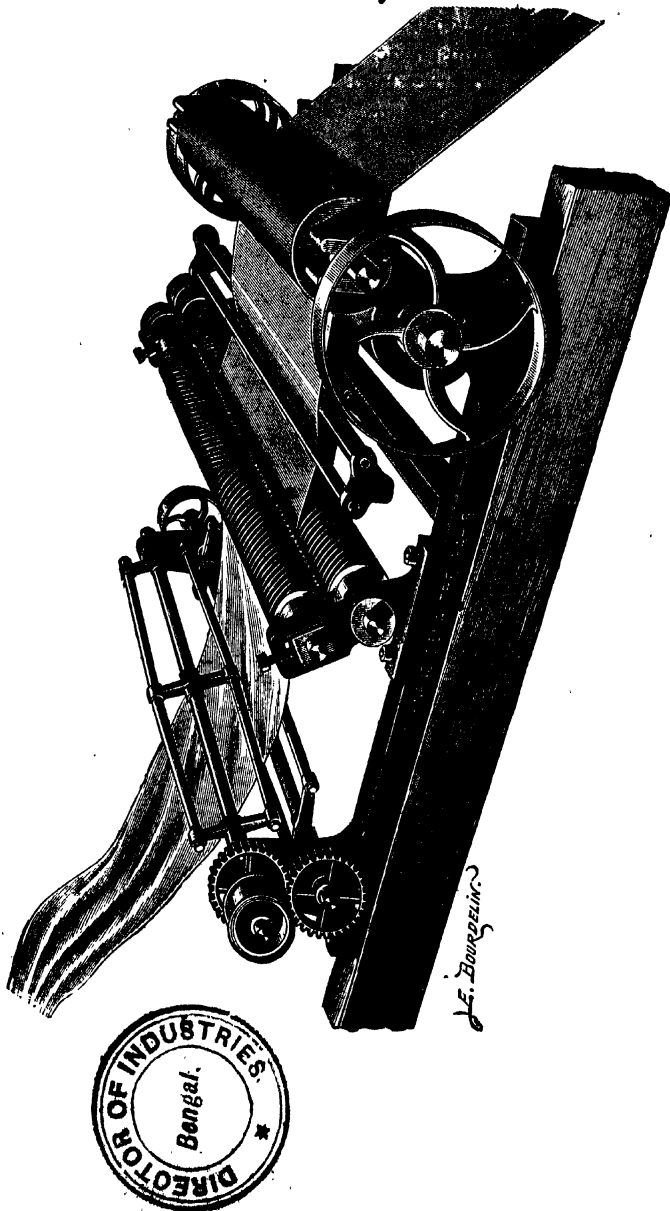


FIG. 48.—Stretcher (Fernand Dehaitre, Paris).

the side opposite to the steam supply. Any risk of collapse of the cylinders through a vacuum being created inside is provided against by atmospheric valves, which are fitted both on the cylinders and on the stands; efficient safety valves and pressure gauges are also fitted to the machine. Fig. 46 is vertical.

2. *Drying by Hot Air*.—In this method of drying the yarn or fabrics are exposed in apartments heated by steam pipes. The yarns are stretched on rods; the fabrics are spread out in the same manner, or, better still, placed horizontally one above the other, supported at regular intervals by horizontal cross pieces. The ends of the pieces are rolled over a wooden bar, to the ends of which two cords are attached, which roll upon a windlass, and by this means the piece is kept stretched throughout its length. Instead of heating the drying apartment by steam pipes, a machine is used which heats the air in contact with the steam pipes, and propels this hot air into the drying room. Whether drying be done by machine or in a heated apartment, care must be taken to remove the air. This is indispensable, for the air soon becomes saturated with steam, and the fabrics to be dried cease to part with their moisture. So that evaporation may go on continuously, the humid air must be expelled and replaced by a fresh quantity of dry air. Drying rooms must therefore be provided with chimneys with a good draught. If powerful ventilation be desired, mechanical ventilator fans are used. The author has employed Blackmann's air propeller with success; it can be easily installed, and requires but little motive power to put it in movement.

3. *Air Drying*.—This is the longest method of drying, but it gives the best results as far as linen and hemp fabrics are concerned. Special drying rooms are constructed for large sheets the length of which varies from 100 to 130 metres (say 110 to 145 yards); they are the length of the pieces, say 130 metres. Their width is such that two rows of pieces may be stretched leaving a wide passage in the middle and two narrow gangways on the sides of 5 metres, 16 feet. The height is $2\frac{1}{2}$ metres, say 8 feet. The sides of the drying room are

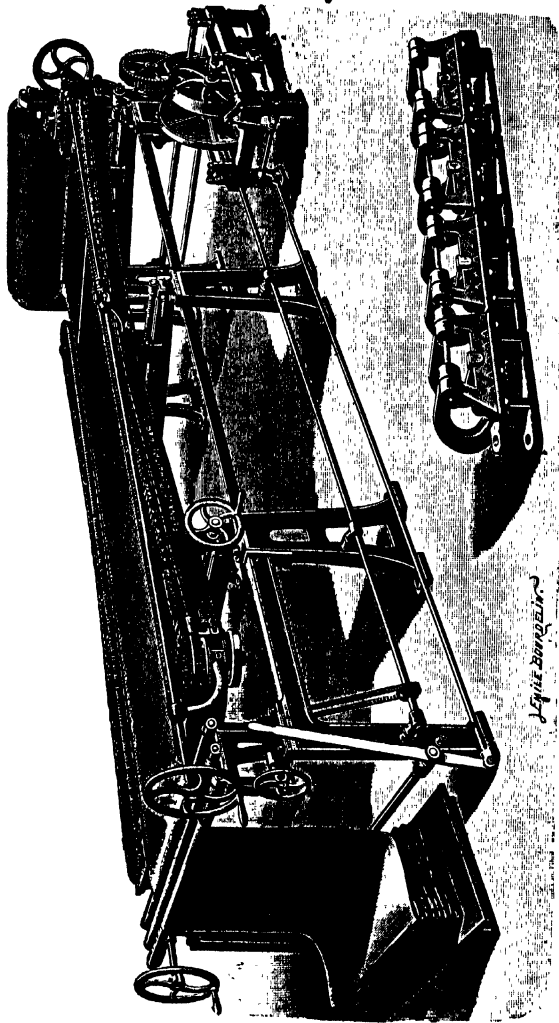


FIG. 49.—Tenter frame (Fernand Dehaitre, Paris).

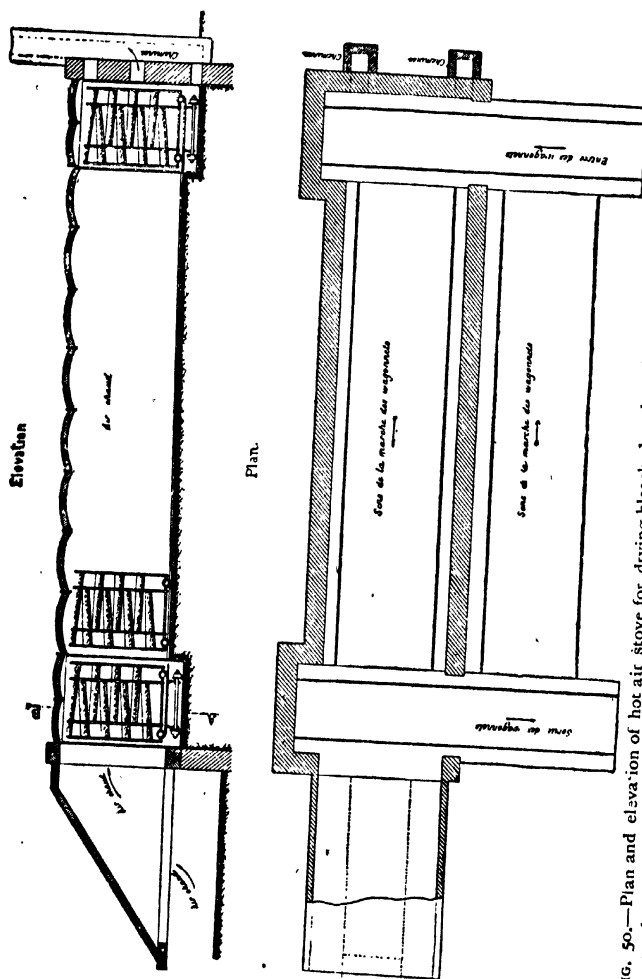


FIG. 90.—Plan and elevation of hot air stove for drying bleached and washed linen and cotton yarn and fabrics in trucks running on rails. *Air chaud* = Hot air. *Sens de la marche des wagonnets* = Direction taken by trucks. *Entrée des wagonnets* = Truck entrance. *Sortie des wagonnets* = Truck exit.

closed by venetian blinds the laths of which are movable round an axis; this enables the room to be aerated in accordance with the state of the atmosphere. Posts placed above the other without touching at a distance of 3 to 4 metres carry horizontal cross pieces on which the lengths of fabric are stretched over.

Fig. 50 shows a plan of a modern hot air dry stove.

CHAPTER XXIII.

DAMAGES TO FABRICS IN BLEACHING AND IN WAREHOUSING.

Yarn—Mildew—Fermentation—Iron-rust Spots—Spots from Contact with Wood—Spots incurred in the Bleaching Green—Mice and Insect Holes—Tar and Grease Spots—Small Holes—Fabrics turning Yellow or Green after Bleaching—Damages arising from the Machines.

BLEACHING is an industry involving fastidious care. The damage which the fabrics may receive in the process may involve the bleacher in serious damages. This damage is often only observed at the finish of the bleaching operations, and it then becomes very difficult to ascertain the cause, and to what defective operation to attribute it. Many injuries are avoided by the bleacher inspecting the fabrics in the course of bleaching, and satisfying himself as to their soundness. If any damage is observed the cause should be at once ascertained, and the injury prevented from spreading further.

Yarn.—Sometimes the warp and the weft are not of the same quality ; hence arises a great difficulty in bringing them to the same degree of whiteness without deteriorating them. When in bleaching fabrics from creamed yarn great annoyance may be caused if the creaming of the thread has been badly done ; the fibre has been more or less attacked, and it is no longer capable of withstanding the operations of bleaching. Bleachers to the trade ought therefore to make stipulations when they bleach fabrics made of creamed yarn, and those firms which bleach their own fabrics should attach much importance to the creaming of their yarn. The yarn for coarse fabrics must be creamed or at least well boiled, but, as far as

the yarn for fine fabrics is concerned, it is much preferable not to cream the yarn before weaving. This permits of energetic washings with lye before the chemick, the operations following are much diminished, and a brighter white is obtained.

Mildew.—This is another stumbling-block for bleachers. It shows itself when the fabrics are three-quarters white; it is very difficult to get rid of, for often, the fabrics being sufficiently white, it is necessary to proceed with further operations so as to get completely rid of it. Mildew cannot be seen in the fabrics until they are almost white, unless under the microscope, and when seen through that instrument some portions of the fabric present a brownish black appearance. The black portions are supposed to be mildew, and to get rid of it requires good lye-boiling, a passage through the stocks, and a strong chemick. The stocks expel it from the fabrics. Mildew is often seen on one side of the fabric and not on the other. If it be noticed that the fabrics at the end of the processes show much mildew, they are to be boiled more energetically and more often; after scouring them give them a good chemick. If the mildew is almost imperceptible, ordinary bleaching operations will cause it to disappear; if it be more accentuated it requires much experience and attention to get quit of it, and preserve the strength of the fabric. A strong sour is regarded by some as a good method for getting quit of mildew, but then it must be put to the sour before it goes to the chemick.

Fermentation.—This is a frequent cause of injury to the fabrics. Great care should be taken to avoid fermentation. The following are the principal circumstances under which it is produced. During steeping, the gum, grease, and resinous matters are dissolved in the tepid water and ferment very quickly. This fermentation is necessary in the beginning to render all these substances soluble, and thus free the fabric from them; but it must be stopped in time so as not to damage the fabric. This preliminary bleaching operation, which would appear inoffensive since it consists of steeping in tepid water, is, nevertheless, one which requires to be executed with the

greatest of care. It is necessary to change the water as soon as it commences to smell badly and is seen to give off bubbles of gas. If the fabric has been damaged, it will not be seen until the bleaching operations are finished, and no one will be able to tell what has been the cause of it. When wet fabrics are left piled in the bleach works they heat and ferment. A rule should be made never to leave them longer than two days in this condition, and if for any cause operations have to be suspended, it is better to dry them. The leaving of fabrics in piles in summer is especially dangerous. Fermentation is more to be feared in those fabrics which are but little advanced in the sequel of bleaching operations. Fabrics on the green in contact with the earth are also liable to ferment, even if exposed on mown grass. In winter they sometimes remain under the snow, resting on the bare ground denuded of all herbage. Fermentation is to be feared, induced by the heat of the earth. If it be impossible to lift the fabrics, the snow should be swept off. The fabrics thus exposed to the cold freeze, and fermentation need no longer be feared.

Iron-rust Spots.—These are common in bleaching; they proceed generally from the fact that the fabrics have, when in the wet condition, come in contact with iron. One moist rust spot makes another. The iron spots on grey fabrics disappear in the course of the bleaching operations. If they are not old they may be removed by hydrochloric acid. But if the fabrics are already white, and it be not desired to employ hydrochloric acid, oxalic acid may be used. Place the stained part above hot water, rub with a little oxalic acid until the spot disappears, and wash well. The spot must be removed on the first attempt, because if the operation has to be repeated, a hole will be driven through the cloth. Spots may be removed with hydrochloric acid in a similar manner. Iron brackets, supports, nails, etc., under the roof should be protected by a coat of paint, and wooden pegs should be used instead of iron nails on stillages, etc.

Spots from Contact with Wood.—Blackish spots appear on fabrics which are allowed to remain on wood, which is always

moist. This happens especially when they are deposited there full of soap from the stocks. These spots may be removed, like iron rust, by rubbing the stained part with hydrochloric or oxalic acid. A sour causes them to disappear partially, but not completely. Care should be taken to prevent the fabrics from coming in contact with oak wood and pine, and generally with every kind of exudation from wood which is not dry, so as to avoid tannin, resin, and other spots. Spots produced by wood sap disappear in the chemicks and sours, those of resin in the alkaline lyes. Do not, therefore, use wood which has not been well dried in the construction of tables on which the fabrics are to rest, or to line the interior of vats, etc. A good precaution is to give the wood a coating of milk of lime, and then to scour it well.

Bleaching Green Stains.—Generally these disappear during the first bleaching operations, but if the fabrics are in the advanced stage of bleaching there remains a red spot which a sour alone can remove. There are black stains made by flowers which are difficult to remove and which require the use of a chemick and a sour. There are also grey stains from the heaps of stones on which the fabrics are deposited. Moss springs up from the cavities and fissures of stones, which are alternately wet and dry; consequently, if the fabrics be allowed to remain there whilst the moss is growing, the latter will stain them. The sour will cause these stains to disappear, but the danger is that supplementary processes will have to be resorted to, processes which injure the strength of the fabrics, and render them thinner than necessary. Earth stains, flower stains, and aquatic moss stains require supplementary treatment for their removal, and care should be taken to prevent their occurrence. There are quite enough difficulties in bleaching without having to resort to fresh processes, which always involve a certain amount of risk. Soot stains and atmospheric dust also cause great annoyance to bleachers. When fabrics well advanced towards the completion of the bleaching processes are stained in this manner, and if the stains cannot be removed by scouring or washing before going to the chemick,

they impregnate the tissue, leaving a black spot which cannot be removed without destroying the fabric.

Insect and Mice Holes.—Damage by insects is rare. Nevertheless, the author has seen larvæ in the folds of fabrics which have made a hole for their escape. A bleacher complained that he had to destroy crickets because they made numerous holes in his fabrics. Ordinary mice and field mice gnaw the fabrics on the green, especially in winter. A small premium is generally given to the bleach works hands for killing them, as well as rats.

Tar and Grease Stains.—Grease stains produced by the oil or grease used for lubrication are removed by vegetable oil. Tar stains are removed by benzine.

Small Holes, Tears.—The former are met with sometimes in fabrics in the advanced stages of the bleaching, small holes of 2 to 3 millimeters in diameter, frequently repeated, sometimes disseminated over the whole piece, sometimes grouped in certain parts. In the latter case, the fabric looks as though it had been riddled by shot from a gun. Opinions differ as to the origin of these small holes, which may be produced during boiling, the steam imprisoned in the folds of the cloth escaping by making holes similar to those made by small shot. Others suppose that they are produced during steeping, either in the chemick or in the sour, without indicating the cause which leads to their production. Tailfer had much worry with these small holes, and the explanation which he gives appears rational to him, without affirming that other causes may not give rise to the same annoyance. It has been noticed that these small holes appear only after the chemick and that they are found in closely woven fabrics, and rarely in loosely spun goods. Now, rain charged with chimney fumes and atmospheric dust falls on the fabrics as they are spread on the green. These fumes contain sulphides (which in contact with the air and with water are transformed into sulphuric acid) and traces of iron, which produce red stains. The fabrics, as they come back from the bleaching green, are generally treated with chemicks without being washed, and

the oxidizing action of chlorine still further accentuates the effect produced on the fibre by the sulphur or iron derivatives, and makes a hole. These holes are not visible immediately, because the attack is not equal throughout. Small holes begin to be observed after the first chemick, then they are more numerous after the second chemick, and so on. It is very probable that the cause which produced them made but a single attack, but as the small spots did not attack the fibres to the same extent, the holes reveal themselves gradually in proportion as the fibre is disintegrated by the chemicals.

Tailfer prevented this damage by carefully washing dust-spotted fabrics on their return from the bleaching green, especially tightly woven goods. When fabrics are nearly white, and when rain is foreseen, which would spot them, it is better to gather them in from the bleaching green or to raise them on to posts, as is done with the large sheetings of Normandy. It does not do to burn any kind of coal indifferently. Coal containing pyrites and much ash, which would give rise to dust, should be rejected.

Tears.—Some of these *may* be due to the rubbing of the cloth against the sides of the keir through tumultuous boiling or by nails in the washing machine, broken or cracked pot eyes, or to wooden parts over which the cloth traverses being worn to a tearing if not a cutting edge by prolonged friction.

Fabrics turning Yellow or Green after Bleaching.—It happens that fabrics turn yellow after they have been stored in a shop or warehouse for a shorter or longer period of time. If they appear green instead of yellow, the cause is the same; it is the union of the yellow with the blue which gives this green cast. Tailfer believes that this may be due to three different causes. (1) Imperfect bleaching: when the fabrics have not been bleached right through there remain colouring principles in the centre of the yarn, which gradually rise up to the surface. In this case the only thing that can be done is to bleach them afresh. The white has not lasted, but the fabric itself is uninjured. A boiling with alkaline lye, a chemick and a sour, or only one of these operations will restore to the fabric its pristine

whiteness. (2) Change in the constitution of the textile fabrics : the chemicals have altered the constitution of the textile fabrics, either because they have been used in too concentrated a state, or because they have not been effectually washed out. Consequently these substances, intended solely for the removal of the colouring principles, continue to act on the fibre under conditions which are peculiarly injurious ; for example, when the fabrics are dried on the green, or drying stove without having been washed. The cellulose, which is the essential part of the fibre, is converted into oxycellulose or hydrocellulose, which assumes a yellow tint after a greater or less lapse of time. The fabric is then more or less tendered. The origin of this yellow may be ascertained by testing the strength of the fabric. Often this yellow tint is partial, and it is found that the tissue is less sound in those parts which have become yellowish than in the parts which have remained white. The evil that has been done cannot be remedied. Chlorine alone will cause these yellow stains to disappear ; alkaline lyes and acids have no effect upon them. Before again drying them they should be washed with the greatest of care, so as to remove every trace of chemical reagents. (3) Obscure or uncertain causes : the fabrics, having been bleached and appearing of a beautiful white, are dried, and immediately become yellow or green if they have been blued (from the union of the yellow with the blue, see *ante*). This yellow or green tint is much more apparent if the fabrics have been dried at a high temperature. The fabrics would not appear to have been tendered in any way, and preserve their soundness. Tailfer often noticed this phenomenon, especially with cottons, and made experiments to find out the cause. The explanations which he endeavours to give are not conclusive, and what follows is simply an hypothesis. The alkaline lyes dissolve the colouring principles, and these substances are afterwards expelled from the fabrics. It is therefore to be supposed that at a certain moment these products have been baked, that is to say, rendered less soluble. That which was on the surface has been removed, but that which remains in the centre of the

yarn has remained there, and, nevertheless, is invisible at the finish of the bleaching processes. If the fabrics be dried at a high temperature, the steam, issuing briskly, brings the coloured products to the surface and causes the yellow or green coloration to appear. Neither chemick nor sour removes this coloration, and recourse must be had to a good alkaline lye-boil. Not knowing the cause of this phenomenon, it is difficult to say exactly what should be done to avoid it. It happens without any apparent change having been made in the process.

When it manifests itself precautions should be redoubled; care should be taken to avoid passing the fabrics from a high temperature to a low temperature, and vice versa. This would occur, for example, if the fabrics, whether impregnated with soap or not, were plunged into boiling lye or boiling water, or if the fabrics as taken from a boiling alkaline lye were plunged into cold water. The fabrics should be heated or cooled gradually.

Some bleachers do not think it right to send fabrics to be finished which have been treated with soap as a final operation. Others think that rosin soap should not be used beyond the lyes which precede the chemick, and that in the succeeding operations olein soap should be used. They think that the former yellows the fabrics. Real rosin soap, rosinate of soda, is soluble in water; its colour varies with that of the rosin from which it is made. When such a soap comes in contact with a calcareous water, a precipitate of insoluble rosinate of lime is formed, and fixed on the fibre. This precipitate is *at first* of a white colour, no matter how dark the original rosin; gradually, however, as it dehydrates it becomes yellowish brown, the depth of colour being equal to that of the original rosin. In other words, the white hydrated rosinate masks the colouring principles, but, when dehydrated by steam drying, it adds to the colour of the fabric that of the rosin from which it was made. If the fabrics have been blued the green coloration is thus easily accounted for. The white rosinate on air-dried fabrics dehydrates on storing or ageing, and the fabrics thus become yellow. The same remark applies to soap

made from dark oils. Hurst ascribed some of the yellow stains to the use of paraffin wax in sizing the wraps and to the use of unsaponifiable mineral oil in lubricating the machinery of the cotton factory.

The laying down or piling of the fabrics in the keirs ought to be carried on in such a manner that the lye thoroughly penetrates the whole mass. If not, it may well happen that certain parts may be strongly heated without being impregnated with lye, and that the colouring principles are baked instead of being dissolved. This latter explanation appears to be deserving of consideration, because the author has found this yellowing to be especially prevalent in fabrics which have been boiled in Mather's keir, and as the fabrics are very tightly packed therein the lye does not always penetrate equally throughout.

Damage Caused by the Machines.—These damages are not so serious as those due to chemicals, because they are more readily seen, and it is more easy to find out the cause. The way to avoid them is to keep all plant and machinery used in bleaching in good working order; to inspect them frequently, and as soon as a flaw or mishap is observed to find out the cause and remedy it. In describing the different machines, the mishaps which may occur in their working have been pointed out.

[THE END.]

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